Here's the loudspeaker line that rocketed to stardom!

IN just a few months after deliveries started, the Western Electric line of high-quality, wide range speakers has won a position of undisputed leadership wherever the ultimate in sound reproduction is desired.

All of these speakers combine, to a unique degree, unmatched realism in reproduction with exceptionally small space requirements and ease of installation. With their range of power capacities, you can select just the speaker you want for every sound radiation requirement.

Have you ordered some? Call your local Graybar Broadcast Representative, or write Graybar Electric Co., 420 Lexington Ave., New York 17, N.Y.

755A—8" direct radiator. 8 watts, 70-13,000 cycles.

756A—10" direct radiator. 20 watts, 65-10,000 cycles.

728B—12" direct radiator. 30 watts, 60-10,000 cycles.

754 TYPE—12" high-efficiency direct radiators. 60-10,000 cycles; 15 watts indoor service, 50 watts outdoor.

757A—dual unit system. 30 watts, 60-15,000 cycles.

THESE ARE AMONG THE BROADCAST STATIONS THAT ARE USING THE NEW WESTERN ELECTRIC LOUDSPEAKERS

ALABAMA
WAFM Birmingham

ARIZONA
KOY Phoenix
KPSC Phoenix
KTSC Tucson
KYSC Yuma

ARKANSAS
KFPW Fort Smith
KWHN Fort Smith

CALIFORNIA
KBMT San Bernardino
KCRA Sacramento
KFAC Los Angeles
KFRC San Francisco
KGFN Grass Valley
KIEM Eureka
KIEV Glendale
KOWL Santa Monica
KRE Berkeley
KSJO San Jose
KUSC Los Angeles
KUSN San Diego
KWIK Burbank

FLORIDA
WALT Tampa
WCNH Quincy
WDAE Tampa
WDBO Orlando
WKAT Miami Beach
WQAM Miami
WSUN St. Petersburg
WTAL Tallahassee

GEORGIA
WCON Atlanta
WGST Atlanta
WNEX Macon
WSB Atlanta

IDAHO
KFXD Nampa
KWEI Weiser

ILLINOIS
WBBM Chicago
WFRL Freeport
WHBF Rock Island
WIND Chicago
WKRS Waukegan
WMBD Peoria
WOAK Chicago
WSOY Decatur

IOWA
KCBC Des Moines
KDEC Decorah
KDTH Dubuque

KANSAS
KIMV Hutchinson
WREN Topeka

KENTUCKY
WGRC Louisville

LOUISIANA
WAFB Baton Rouge
WCLA Baton Rouge
WTPS New Orleans

MASSACHUSETTS
WBZ Boston
WLYH Lynn
WNAC Boston

MICHIGAN
WELL Battle Creek
WHRV Ann Arbor
WJBK Detroit
WKAR Lansing
WWJ-TV Detroit

MINNESOTA
KAUS Austin
KBTR Minneapolis
KSTP Minneapolis
WCCO Minneapolis
WEBC Duluth
WMIN Minneapolis
WTCN Minneapolis

MISSISSIPPI
WLOX Biloxi

MISSOURI
KHMO Hannibal
KWK St. Louis
KWTO Springfield
WIL St. Louis

MONTANA
KIYI Shelby
KOJM Havre
KPRK Livingston

NEBRASKA
KFAB Omaha
KOWH Omaha

NEW JERSEY
WPAT Paterson

NEW YORK
WJZ New York

NORTH CAROLINA
WDNC Durham
WFMY Greensboro

NORTH DAKOTA
KVOX Fargo

OHIO
WADC Akron
WEWS Cleveland
WHIZ Zanesville
WHIO Dayton
WHK Cleveland
WHKC Columbus
WHKK Akron
WJW Cleveland
WOSU Columbus
WSPD Toledo
WSRS Cleveland Heights

OKLAHOMA
KGLC Miami
KOMA Oklahoma City
KSIW Woodward
KSPI Stillwater
WKY Oklahoma City

OREGON
KALE Portland
KGW Portland
KPFM Portland
KUIN Grants Pass

PENNSYLVANIA
KDKA Pittsburgh
WCAE Pittsburgh
WCRO Johnstown
WHJB Greensburg
WHOD Homestead
WJAS Pittsburgh
WJSW Altoona
WKJF Pittsburgh
WKRZ Oil City
WMBS Uniontown
WMCK McKeesport
WMGW Meadville
WPGH Pittsburgh
WPIC Sharon
WBVP Beaver Falls

RHODE ISLAND
WEAN Providence

SOUTH CAROLINA
WIS Columbia

SOUTH DAKOTA
KELO Sioux Falls
KSDN Aberdeen
KSOO Sioux Falls

TENNESSEE
WHIN Gallatin
WMAK Nashville

TEXAS
KABC San Antonio
KCMC Texarkana
KLEE Houston
KMAC San Antonio
KRLD Dallas
KTRM Beaumont
WBAP Fort Worth
WFAA Dallas

VIRGINIA
WRVA Richmond

WASHINGTON
KBRC Mt. Vernon
KBRO Bremerton
KOMW Omak
KONP Port Angeles
KRSC-FM Seattle
KTBI Tacoma
KVNI Spokane

WEST VIRGINIA
WAJR Morgantown
WCOM Parkersburg
WLOG Logan
WLON Princeton
WMMN Fairmont
WPDX Clarksburg
WPLH Huntington

WISCONSIN
WATK Antigo
WCLO Janesville
WEAU Eau Claire
WIBA Madison
WJMC Rice Lake
WJPG Green Bay
WKBH La Crosse
WMIL Milwaukee
WOBT Rhinelander
WTAQ Green Bay
WWCF Poynette

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OFFICES IN 95 PRINCIPAL CITIES

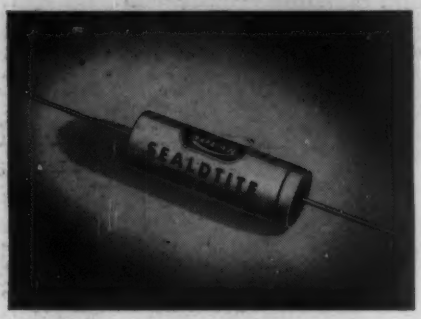
Western Electric

—QUALITY COUNTS—

The Solar System

electronics edition • June 1948

NOW! HIGH-VOLTAGE HI-TEMP* SEALDTITE* TELEVISION TUBULARS



Dependable, yet moderately priced high-voltage molded paper capacitors for television receivers are the latest capacitor development to be introduced by Solar.

These new capacitors, latest addition to the famous Solar "Sealdtite" series, are impregnated with mineral oil and molded in Hi-Temp plastic compound for service at ambient temperatures up to 100°C.

Identified as Solar Type STM, high-voltage Hi-Temp Sealdtites are available in standard voltage rating of from 2000 to 6000 volts.

The use of moisture-proof molded housings makes possible a surprising reduction in capacitor size over conventional cardboard type design. The maximum capacitances available in the ¾" x 2⅛" mold size, for example, are as follows: .035 mf @ 2000 wvdc; .03 mf @ 2500 wvdc; .02 mf @ 3000 wvdc; .015 @ 3500 wvdc; .01 mfc @ 4000 wvdc; .005 @ 4500 wvdc, 5000 wvdc and 6000 wvdc.

Complete listings of standard ratings and sizes are given in Solar Catalog Bulletin SPD-200. Write for your copy today.

Solar Manufacturing Corporation
1445 Hudson Blvd., North Bergen, N. J.

★Trade Mark

SOLAR CAPACITORS
"Quality Above All"

BUSINESS BRIEFS

By W. W. MacDONALD

Biggest Customer for many RMA member-companies in 1947 was Uncle Sam. Here's the way communications equipment sales (exclusive of home receivers) broke down, most of the volume covering transmitters and associated apparatus:

U.S. Government	$48,548,676
Broadcast Stations	25,868,781
General Users	9,631,332
Aviation	3,591,633
Marine	292,389

Uncle was first by a wide margin on electronic navigation equipment, including radar and sonar:

U.S. Government	$81,320,455
Aviation	2,823,571
Marine	769,743

And Uncle bought $4,601,257 worth of our laboratory and test equipment.

Movie People, now very conscious of the competition presented by home television, are out of the talking and into the doing stage. Paramount recently relayed a spot news event into a New York picture palace, transferred it to a film and ran the film thirty seconds later. The audience, not told about the stunt at the box office, took the program for granted.

Watch for more of this sort of thing, without benefit of cooperation from broadcast stations.

Multiple-Screen Tele, an idea broached some time ago in this column (p 68, March), appears to be taking hold. Commercial installations involving one set and several remotely-operated cathode-ray tubes have been made in taverns in the New York area. Adaptation of the scheme to home sets appears certain to follow.

Indoor Tele Antennas are badly needed, thought many dealers attending *Televiser's* recent show at the Hotel New Yorker. It seems that thousands of apartment-house families are number-one prospects for sets but, for various reasons, see little chance that they can be connected to outdoor or master antenna systems for years to come.

Things that the public want have a habit of coming true, despite technical difficulties. One possible solution of the indoor tele antenna problem involves a compact directive array positioned to catch signals on the second or third bounce off building walls, in conjunction with a preamplifier. Any other ideas floating around out there?

Major Impression gained at a recent meeting in Philadelphia attended by tube manufacturers and designers of industrial electronic equipment is that it is silly to put a $1 tube in a $1,000 control attached to a $10,000 machine unless the tube is completely suited to the application.

Makers of controls, it seems, are willing and anxious to spend more for tubes that have predictable life, particularly if they can be sure such tubes will be available on a long-term basis.

Miniature Tubes are in such demand that occasional shortages are anticipated. At least one manufacturer is urging equipment designers to play safe by (1) using types available from three or more suppliers, (2) planning chassis layouts readily convertible to octals and, (3) arranging to use miniatures having either of two base layouts.

Prediction by one tube maker is that by 1950 miniatures will represent 60 percent of receiving-type production, metal 20 percent and conventional glass 20 percent.

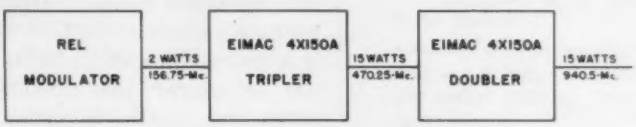
We Hear That Sperry Gyroscope has just received a contract from the U. S. Coast Guard for 20 loran sets. Some 40 sets were bought back in June of last year. Several aid weather ships to keep on their stations.

Just About Everything is used in the field of electronics. The other day we saw a camera set up to take pictures of oscilloscope

15 WATTS AT 940.5-Mc. with the EIMAC 4X150A TETRODES

FREQUENCY UP 6X, (156.75-Mc. to 940.5-Mc.)
POWER UP 7X (2 watts to 15 watts)

Here's a STL transmitter that's in operation on the new 950-Mc. band, fulfilling all the FCC requirements and powered by Eimac 4X150A tetrodes. It's a part of the studio-transmitter-link between the San Bruno studios and the 250 Kw FM transmitter of station KSBR high atop 3849-foot Mt. Diablo some 33 miles away.



The R-F amplifier was specifically designed for the KSBR application by Eimac engineers. It is driven by an REL modulator delivering 2 watts output at 156.7-Mc. to one Eimac 4X150A in a tripler stage, which in turn drives a single 4X150A in a doubler stage, providing 15 watts useful output at 940.5-Mc.

The Eimac 4X150A is ideally suited for this application because of its high power gain at relatively low plate voltages, ability as a frequency multiplier without loss of amplification, low grid drive requirements, and a high ratio of transconductance to capacitance. It also has the advantage of being physically small and functionally designed for simple installation.

Complete data on the Eimac 4X150A for STL and other UHF applications is available by writing direct.

EITEL-McCULLOUGH, INC.
197 San Mateo Avenue, San Bruno, California

EXPORT AGENTS: Frazar & Hansen—301 Clay St.—San Francisco, Calif.

Eimac 4X150A

ESSENTIAL DATA
KSBR STL TRANSMITTER

REL MODULATOR, MODEL 694
EIMAC 4X150A, R-F AMPLIFIER

Useful Output Power	15 watts
Frequency	940.5 Mc.
Frequency Stability	.002%
Audio Frequency Response. Substantially flat	50 to 15,000 cycles
Distortion	.5% Max.
Noise Level	70 db below 100% modulation
	± 100 Kc. deviation

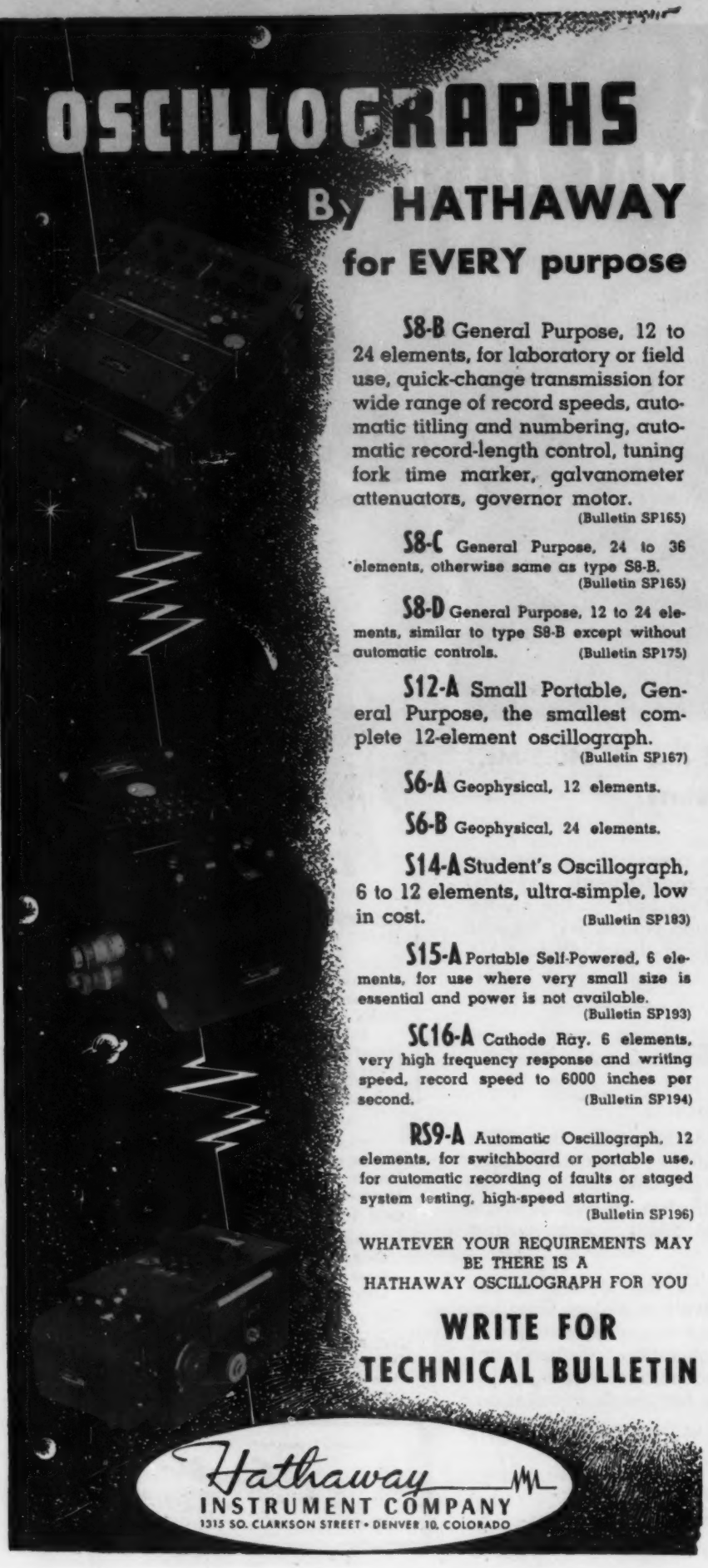
Eimac 4X150A
General Characteristics

Heater voltage	6.0 volts
Heater current	2.8 amps.
Minimum heating time	30 secs.
Grid Screen amplification factor	4.5
Direct interelectrode capacitance (Average)	
Grid-Plate	0.02 μμf
Input	14.1 μμf
Output	4.7 μμf

Maximum Ratings

D-C Plate voltage	1000 volts
D-C Plate current	250 ma.
Plate dissipation	150 watts
D-C Screen voltage	300 volts

Follow the Leaders to *Eimac* TUBES
The Power for R-F


OSCILLOGRAPHS
By HATHAWAY
for EVERY purpose
S8-B General Purpose, 12 to 24 elements, for laboratory or field use, quick-change transmission for wide range of record speeds, automatic titling and numbering, automatic record-length control, tuning fork time marker, galvanometer attenuators, governor motor. (Bulletin SP165)
S8-C General Purpose, 24 to 36 elements, otherwise same as type S8-B. (Bulletin SP165)
S8-D General Purpose, 12 to 24 elements, similar to type S8-B except without automatic controls. (Bulletin SP175)
S12-A Small Portable, General Purpose, the smallest complete 12-element oscillograph. (Bulletin SP167)
S6-A Geophysical, 12 elements.
S6-B Geophysical, 24 elements.
S14-A Student's Oscillograph, 6 to 12 elements, ultra-simple, low in cost. (Bulletin SP183)
S15-A Portable Self-Powered, 6 elements, for use where very small size is essential and power is not available. (Bulletin SP193)
SC16-A Cathode Ray, 6 elements, very high frequency response and writing speed, record speed to 6000 inches per second. (Bulletin SP194)
RS9-A Automatic Oscillograph, 12 elements, for switchboard or portable use, for automatic recording of faults or staged system testing, high-speed starting. (Bulletin SP196)
WHATEVER YOUR REQUIREMENTS MAY BE THERE IS A HATHAWAY OSCILLOGRAPH FOR YOU
WRITE FOR TECHNICAL BULLETIN
Hathaway
INSTRUMENT COMPANY
1315 SO. CLARKSON STREET • DENVER 10, COLORADO

traces, and the darn thing was held in position by Erector-set parts.

Receiver Sales by RCA licensees during 1947 totalled 20,174,370 units, worth $702,798,118. Here's the way the total broke down:

TYPE	UNITS	DOLLARS
Electric		
Table (under $12.50 billing price)	2,206,472	$23,331,200
Table (over $12.50 billing price)		
A-M	7,873,379	150,553,298
A-M/F-M	201,366	10,702,645
F-M (including converters)	72,654	1,840,705
Consoles		
A-M	132,804	13,581,187
A-M/F-M	42,898	5,412,652
Table-Radio-Phonos		
A-M	1,302,491	63,554,888
A-M/F-M	3,581	619,549
Console-Radio-Phonos		
A-M	953,356	96,566,151
A-M/F-M	765,780	123,570,950
Battery		
PortableA-C/D-C	2,427,613	54,565,628
Table	513,536	10,866,683
Consoles	4,014	599,014
Auto	2,862,466	87,120,288
Television		
Converters	.....	.....
Radio Table Models	103,673	22,528,406
Radio Consoles		
Direct viewing	18,551	6,420,776
Projection	10,795	6,175,514
Radio Phonos		
Direct viewing	17,400	7,724,026
Projection	372	613,521
Phonographs		
Phono only	467,605	10,033,767
With radio attachment	74,271	2,100,013
Without Cabinets		
A-M	101,810	2,577,098
A-M/F-M	17,436	1,725,391
Television	47	14,588
TOTAL	20,174,370	$702,798,118

Panel Instruments having 270-degree scales were developed during the war to simplify the reading of necessarily compact types. Now we note with interest that the idea is coming into more widespread use in power instruments both large and small. It seems to us that spreading out of scales is particularly important in the field of electronics, and that the idea merits extension to our kind of apparatus.

Radar Rat Trap promoted by an outfit up in Rochester intrigues us no end. If we were a betting man we'd offer two to one that while the thing may catch rodents it doesn't detect their presence by reflected radio waves.

Philco Sales in 1947 broke down as follows: refrigerators, freezers and air conditioners 32 percent; radio-phonographs and tele-

vision receivers 30 percent; radio sets 24 percent; tubes, parts, dry batteries, accessories and miscellaneous products 9 percent; government and industrial business 5 percent.

Stromberg-Carlson's 1947 sales were split three ways: radio 65 percent; telephone 31 percent; sound 4 percent.

Allen B. DuMont manufacturing division sales in 1947: television receivers $7,774,000; cathode-ray tubes $1,846,000; cathode-ray oscilloscopes $1,702,000 and television transmitters $517,000.

Vernier Dial designed by one of our readers (p 68, April) appears to interest quite a few manufacturers looking for new things to make, and we have forwarded their inquiries to the designer. Anyone else out there we can help in a similar manner?

Magnet Wire produced in 1947 totalled 300 million pounds, according to the best estimates we have been able to obtain. About one third of this wire went into electronic apparatus.

Best Argument cathode-ray tube makers have for limitation of the number of television types is the cost reduction that can be obtained by mass production. Many students of the current trend toward lower-priced sets believe that savings that might be achieved by variations in tube design at this time are minor by comparison.

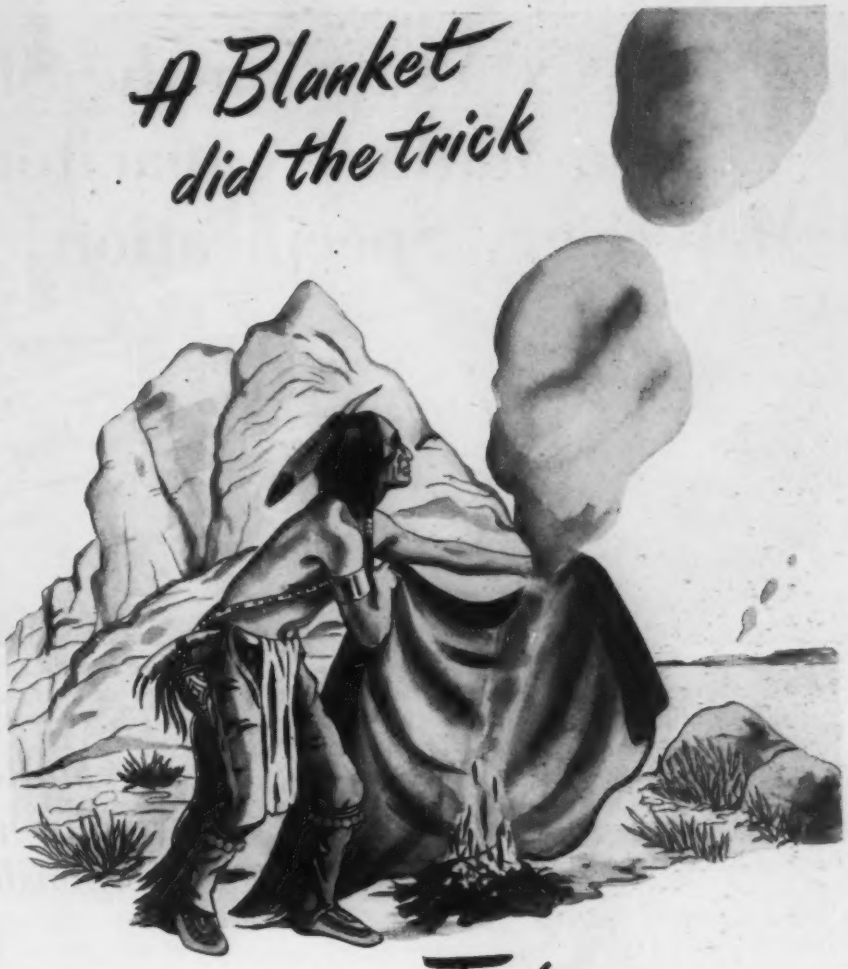
Highest Priced item ever offered by GE for use in the home is a new a-m and f-m phono-radio and television set listing at $2,100.

Government Specs cover over 4,000 tube types.

Norm Krim of Raytheon says it costs at least $50,000 to develop a really new tube.

New To Us is an expression heard the other day in a laboratory. We arrived in the middle of an obvious flurry of excitement. Questioned regarding the cause, one of the engineers replied, quite casually, that he thought it was just a *"routine emergency."*

A Blanket did the trick



Today... the COIL'S the thing

It's a far cry from smoke signals to electronic communications. And at the heart of electronics lies the coil. We wind coils of great variety for many uses and our 30 years of experience is at your service. Send us your specifications. We shall be glad to quote.

COTO-COIL CO., INC.
COIL SPECIALISTS SINCE 1917
65 Pavilion Ave., Providence 5, R. I.

After Six Years on the Shelf —These Mallory Capacitors Met Every Specification!

The proved long shelf life of Mallory Capacitors is a plus value to the man responsible for Inventory

When you buy capacitors it's a relief to know that, should your production program change, the stock on hand may be held without becoming useless through deterioration. Mallory Capacitors have proved on many occasions that they can take long periods of storage without loss of efficiency.

We recently tested capacitors for several customers* who had shelved them for up to six years. All proved ready to use without re-aging. None took more than seven minutes to reach the leakage limit of new units. All characteristics were within the limits of new-unit inspection.

Such quality is added protection for the man who specifies Mallory Capacitors. Such quality is invariably built into Mallory Approved Precision Products.

*Names on request.

Yours for the asking!

Everything you want to know about Mallory electrolytic capacitors—types, sizes, electrical characteristics—even data on test measurements and mounting hardware!

BUY MALLORY ASSURED QUALITY AT REGULAR PRICE LEVELS

P. R. MALLORY & CO. Inc.

MALLORY CAPACITORS

(ELECTROLYTIC, OIL and WAX)

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

CROSS TALK

► **INTERCARRIER** . . . One of the tempests raging in the television field is that around the intercarrier method of receiving the sound. In this system (see ELECTRONICS, Jan. 1947, p 102), the picture and sound carriers are amplified together in the picture i-f amplifier, developing a 4.5-mc beat frequency (the separation of picture and sound carriers) at the picture tube grid. This beat note is frequency modulated by virtue of the f-m on the sound carrier and hence may be passed through a limiter, frequency detector and audio amplifier to the loudspeaker. At first this idea sounded attractive principally on the grounds of economy, since no sound i-f amplifier is needed. Soon the economy idea was replaced by recognition of advantages relating to the shortcomings of the local oscillator in a standard receiver. The intercarrier system is highly tolerant of drift, microphonics and hum modulation in the local oscillator, since these affect the carriers in the same degree and hence do not disturb the 4.5-mc beat note. An intercarrier receiver would, in fact, require no fine tuning control.

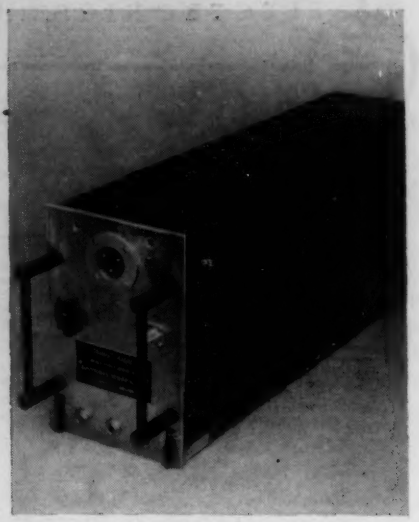
Then a manufacturer was so brash as to bring out an inexpensive video receiver using the intercarrier system. Brash, because mutterings had been heard from the first that the system would fail if the picture carrier was frequency modulated to any extent by the picture waveform. Then a low pitched (60-cps) rattle which could not be separated from the sound modulation would appear at the loudspeaker. To be sure, interference of this type was soon discovered, particularly when the picture modulation was heavy, but the effect was not pronounced and certainly was tolerable in an inexpensive receiver. At least so it seemed on the low-band stations then on the air.

So the inexpensive sets continued to sell, and the mutterings of the transmitter manufacturers continued to be heard, and action to recommend to the FCC standards which would safeguard against excessively heavy picture modulation continued to be deferred. Then a station on channel 13 opened up in the New York area. This channel, on 210–216 mc, was expected to give the most trouble from unavoidable frequency-modulation of the picture carrier. But when listening tests were carried out, the intercarrier sets seemed to do as well, or nearly, as on the low band stations. The conventional receivers, for the most part, gave considerably inferior performance, due to hum modulation, microphonics and drift of the local oscillator, in the order named.

Thus often is confidence misplaced. The transmitter men had done better than they thought; the receiver men had done worse. The argument is not over yet. But the inexpensive receivers continue to sell and the recommended standard continues to be deferred. Our guess is that when enough of the intercarrier receivers are sold, the transmitter designers will have to lick incidental frequency-modulation of the picture or lose customers, and the broadcasters will have to monitor modulation or lose a good part of their audience. We don't argue for such de facto engineering, based on sales figures, but we recognize its power.

► **DECISION** . . . Since we commented in February on the care with which marine radar must be used as an anti-collision device, a Canadian court has ruled, in another case, that the use of radar does not free the master of a vessel from the established rule of the sea, namely that he must operate at such speed as to be able to stop within a distance not greater than one-half the range of visibility. Visibility here means the distance the lookout can see with human, not radar, vision. If this decision establishes a precedent in admiralty law, the utility of radar in the marine field will be sharply restricted. No captain would dare run through fog at high speed with radar guidance if by so doing he placed himself and his owners in the position of being legally responsible for any collision which might occur, regardless of other circumstances. Before the courts can be expected to take a more liberal view, an impressive record of safe operation of radar-equipped vessels must be amassed. That drives the point home: radar is a safety aid only when it is properly installed, adequately maintained and intelligently used.

Loudspeakers above the aisle of this Portland, Oregon trolley bus provide music for riders



Fixed-tuned f-m broadcast receiver for bus radio service

Car-Card Radio

THE BANNS have been proclaimed for an interesting four-way marriage of transportation, f-m radio broadcasting, the riding public, and advertising. Proponents of the scheme claim that all the participants gain.

The Basic Idea

Predicated upon the fundamental premise that riders of a transportation system are captive during the period of their travel, the advertiser can be assured of a measured number of listeners to his sales talk for any given day and time of day. In return, the rider gets free music and news. Bus systems feeling the pinch of increased operating costs will welcome any device that supplements revenue from the sometimes provocative but as yet unvocal "car cards". And the station that keys its programs to the new advertising medium can be expected to reap some additional revenue at a time when f-m broadcasting needs it.

The broad contractual aspects of the system are simple. The f-m station enters into an agreement with the local transit company that provides exclusive rights for the broadcaster to install receiving equipment in the vehicles. The radio station pays a monthly fee to the transit company for each radio-equipped vehicle, in the manner of recompense for car card advertising. Another contract is made between the broadcaster and the organizing agency that provides for purchase of receiving units and all accessories (currently selling for about $141) and the appointment of the agency as exclusive advertising representative.

Taking the narrow view (the small city bus line) the suggested system of transportation radio looks simple; but ad men thinking in terms of the broad golden field are already causing engineers some worry. For example, interest has already been shown by certain railroads.

While the bus can get along with a normally sensitive, single-channel receiver, the railroad car must be equipped to pick up weaker signals at greater distance on a receiver that can be tuned from one frequency to another as the train progresses from one service area to another along its route. There is then nothing to insure that the receiver is tuned to the program desired by the sponsor of the service. Length of time that a given station will be heard satisfactorily depends not only upon transmitted power from the antenna but also upon such diverse factors as speed of the train and terrain between the transmitter and the moving receiver.

Planes are a special and more difficult problem.

Programming Problems

Transportation authorities are already discussing contracts that insure a minimum amount of advertising material, both as to length and frequency. Programs can't be all boogie-woogie or all Shostakovitch. The idea of a sports broadcast is enough to make any transportation executive's hair

Table 1—Announcement and Time Rates for 400 Receivers

	1 Time	13 Times	26 Times	52 Times	104 Times	260 Times	500 Times	1,000 Times
Announcements								
Class A (23,000 riders) 7–9 am 4–6.30 pm	$20.00	——	$19.00	$18.00	$17.00	$16.00	$15.00	$14.00
Class B (8,200 riders) 6–7 am 9 am–4 pm	10.00	——	9.50	9.00	8.50	8.00	7.50	7.00
Class C (4,400 riders) 6.30 pm–midnight 12–12 Sunday	6.00	——	5.70	5.40	5.10	4.80	4.50	4.20
Time Rates								
6.30 pm–midnight								
1 hour	40.00	38.00	36.00	34.00	32.00	30.00	——	——
1/2 hour	24.00	22.80	21.60	20.40	19.20	18.00	——	——
1/4 hour	15.00	14.25	13.50	12.75	12.00	11.25	——	——

Radio programs keyed to a captive listening audience in buses, trolleys, and trains constitute a new advertising medium and source of revenue for the f-m broadcaster

curl. What if the bell rings at the count of nine just as the bus pulls into the terminal! At the same time, the radio station can not afford to key its entire production into a transportation receiving system. There is, of course, the possibility of turning bus receivers on or off with an ultrasonic tone. Broadcasters turn pale when the riders' radio scheme is compared to the Muzak system of music supplied by wire to restaurants and other public places where music is designed, as are the murals or the drapes, as a backdrop for more important activity. The system is no source of revenue if the riders' consciousness is not pricked. And the Federal Communications Commission would undoubtedly view with disfavor a broadcasting system using conventional f-m frequencies to concentrate a narrow type of program material in the manner of point-to-point communication. Quite aside from the strictly legal aspects, the broadcasters realize that concentration on transportation radio to the exclusion of the greater potential audience would knock the whole business flat on its face.

Because there are inherently few technical problems that can not some how be overcome by competent engineers, the greatest potential impediment to adoption of car-card radio would seem to be the rider himself. Judging from the surveys that have so far been publicized, the public can be expected to lap it up. Better than 95 percent of those queried have indicated that recently broadcast test programs of music and news were not only acceptable but enjoyable. Of 2,626 interviews completed among the riders on five different lines in or near Cincinnati between the hours of 9 am and 6 pm, 2,514 indicated enjoyment, 84 did not enjoy the program, and 28 maintained a neutral attitude.

Although the idea of car-card radio is spreading rapidly and negotiations are in progress in a number of cities, the only firm rates available at the time of this writing were furnished by Louis E. Schaefer of Transit Radio, Inc. for WCTS-FM, Cincinnati, Ohio. This station operates on 101.9 mc (Channel 270) with an effective output power of 12.6 kw. Under a contract with Transit Radio, Inc., there are to be 400 single-frequency f-m receivers placed on vehicles of the Cincinnati Street Railway Co., the Covington, Cincinnati and Newport Railway Co., and the Dixie Traction Co. The audience is estimated at 380,000 riders per day. Guaranteed average circulation has been divided into three classes, the rates for which are shown in Table I. Announcements must not exceed 35 words. Three-minute news periods and sports summaries in which the total commercial time must not exceed 50 words is charged for at the announcement rate plus 50 percent. Weather reports and time signals are handled at special rates. The time rates for programs in excess of 3 minutes are covered only in the second Class C category.

Equipment

Under the normal conditions so far encountered, adequate signal has been obtained using a dipole antenna mounted horizontally above the front windshield (so as not to interfere with conveyor-type bus cleaning operations). A 50-ohm line connects the antenna to the receiver installed under one of the passenger seats.

The receiver itself is a crystal-controlled, fixed-tuned superheterodyne with eleven miniature tubes. Frequency response is within ± 2 db from 50 to 10,000 cycles, with an audio output of 8 watts. Ordinarily six 6-inch permanent magnet speakers mounted along the ceiling of each bus are adequate. Two volume controls are provided; one a master that is locked into place at the time of installation; the other a vernier control for adjustment over a 6-db range. Power is supplied from a dynamotor operating from the vehicle's battery. At 12 volts input the drain is less than 8 amperes. The receiver is shock mounted and any component weighing over 5 grams is tightly fastened to a terminal board so as to avoid breakage from vibration or jarring.—A. A. McK.

Engineering the Schematic Diagram

Step-by-step procedure for preparing intricate diagrams so that major circuitry stands out clearly, with stages arranged according to mechanical groupings of equipment yet still in logical order. Diagrams for APS-3 radar serve as examples

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THE IDEAL schematic diagram should present the features of a circuit in a form which is suitable for ready analysis in the fashion of the flow-of-function outline, exemplified by the organization chart, the production-line flow, the chemical-process diagram and other systematized arrays of information.

Diagramming with lines which show only circuit components and their interconnecting copper wires, without a scheme, produces an impenetrable labyrinth when extended without refinement to modern complex electronic equipment. The scheme is the essence, and effective schematic diagrams should display clearly:

(1) A readily discernible pattern or general framework of the system that stands out boldly from a background of accurate but subordinate detail.

(2) The sequence of events or operations, such that cause is plainly related to effect, and the directions of flow of power, signals, impulses and functions.

(3) The relative importance of components or units.

(4) The roles that individual components play in circuit operation.

(5) Certain broad mechanical features of grouping of construction.

(6) The physical points of ready access to the circuits where tests may be applied, measurements made, or results obtained.

(7) The controls as to name, physical position, how the adjustment is made mechanically, how the controls are related to other controls and to the influences they exert.

(8) Copious annotations, including electrical values of components.

Careful planning of a clear, rich schematic calls for the expenditure of time, thought, and ingenuity to achieve clarity and smoothness. It must be sketched again and again, rearranged and sketched over. A good schematic cannot be drawn casually. It must be done by one who knows thoroughly the operation and purposes of the equipment.

FOR SIMPLIFIED MAINTENANCE

Increasing ingenuity in developing electronic devices today demands that a correspondingly high order of skill be devoted to lucid recording of their circuitry.

The techniques described here for enhancing the clarity and value of intricate schematic diagrams were successfully used during the War throughout the Massachusetts Institute of Technology Naval Radar School.

Extra time spent in planning and execution of diagrams for commercial radar, communication and industrial electronic control equipment will more than pay for itself in simplification and speedup of maintenance and servicing

The Block Diagram

The positions on the paper of all parts of the drawing should conform to a general framework or plan which shows the flow of function. This bare framework is called a block diagram. It should first be sketched out in as ideally simple and straightforward a manner as possible. The flow begins with the primary motivation of the equipment, generally at the left of the sheet. As the activating impulse or signal is carried through successive operations, such as amplification, reshaping, phasing, and the like, heavy black flow lines should be drawn toward the right, passing through these operators or modifiers sketched in as unit-function blocks without regard to their physical locations in the equipment.

By unit-function block is meant a whole circuit operating as a unit, such as an amplifier, multivibrator, or oscillator. The path may branch and proceed through parallel paths or it may be joined by paths of impulses coming in from blocks above or below the main flow. For eye appeal, consecutive order, and readability, the flow should be kept moving in smooth unbroken streams from the cause, on the left, to the effect on the right.

Having sketched an ideally smooth flow, as illustrated by the diagram of an APS-3 radar equipment shown in Fig. 1, it will be necessary to modify this to some

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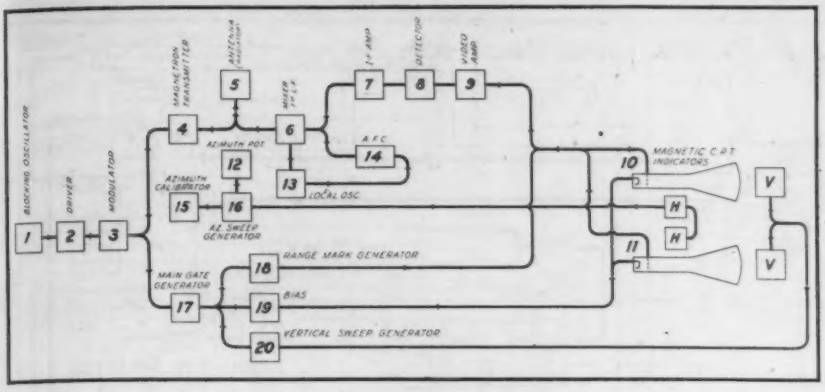

FIG. 1—First draft of block diagram, showing idealized flow of functions for APS-3 radar

extent to conform to the actual physical locations of the unit-function blocks in the equipment.

By moving these blocks up or down it will be possible to collect, in one general group on the sheet, those which are located in the same mechanical unit or box. Such a step is illustrated in Fig. 2. This will require the flow lines to dip downward or upward from the original ideal path. Any rearrangements which result in straighter flow lines or emphasis upon the relative importance of the paths should be used. This will often require related units to be above each other.

The blocks related by physical location are enclosed by a larger dashed outline, boldly drawn, designating the frame, unit, or box which contains them. Within this outline the blocks may be shifted about to preserve straight flow lines and to eliminate as many crossovers of paths as possible. From the schematic viewpoint these outlines may be rectangles, long, short, horizontal, vertical, notched, or otherwise shaped to accommodate blocks, without regard to similarity to the actual box shape in the equipment.

Frequently it is desirable to prepare the entire schematic so that it can be separated into individually complete numbered pages. This arrangement is particularly useful for instruction book or text book purposes. The appropriate section of the entire drawing may also be secured inside covers or doors of the individual apparatus boxes or cabinets. When the worker studies the overall system schematic drawing, he encounters the same familiar diagram patterns which he finds in the covers of the individual units. To provide this page sectionalization, additional rearrangements of the drawing may be required so that reasonable divisions can be made. In general this is not too difficult once the mechanical grouping of unit-function blocks has been determined.

Figure 3 illustrates a rearrangement of the material of Fig. 2 into four separate quadrants or pages. Helpful general details have been filled in to form the complete block diagram as finally developed. The quadrant or page numbers refer to detailed drawings, one of which is shown in Fig. 4. Note the very close correlation between the patterns of the heavy flow lines on Fig. 3 with their counterparts on the detailed drawings of Fig. 4. For the reader, this preservation of the pattern simplifies the mental transition from block diagram to individual page. It is also a powerful assistance to the memory.

The Detailed Sheet

The positions of the unit-function blocks having been roughly determined by the layout of the block diagram, it becomes necessary to develop the detail within each block. This detail comprises resistors, capacitors, coils, tubes, etc, whose wiring must fit into the general scheme.

To achieve smoothness, it may be necessary to draw and redraw the circuitry of blocks top for bottom or right for left to conform to the straightforward block diagram. It should always be kept in mind that each block is a subsidiary link in the branching chain-of-function flow.

The component resistors, capacitors, and tubes should be so disposed with respect to each other that the circuit behavior and purpose is made clear. This may require readjustment of the block diagram as space requirements become defined. Where voltage divider chains of resistors provide graduated voltages, they should be arranged in the simple straight line or row with the high voltage impressed across the ends. Successively lower-voltage taps come out from it like steps in a ladder. A convenient concept is a potential gradient of the tapping wires:

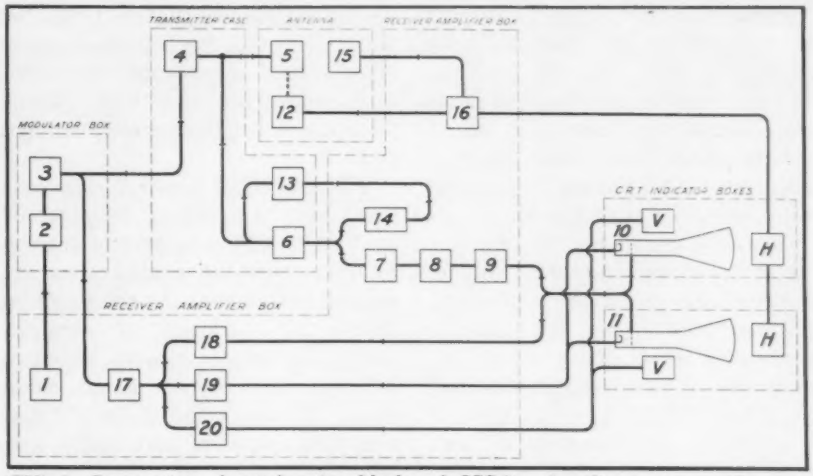

FIG. 2—Regrouping of unit-function blocks of APS-3 radar diagram to conform to mechanical divisions and minimize crossovers

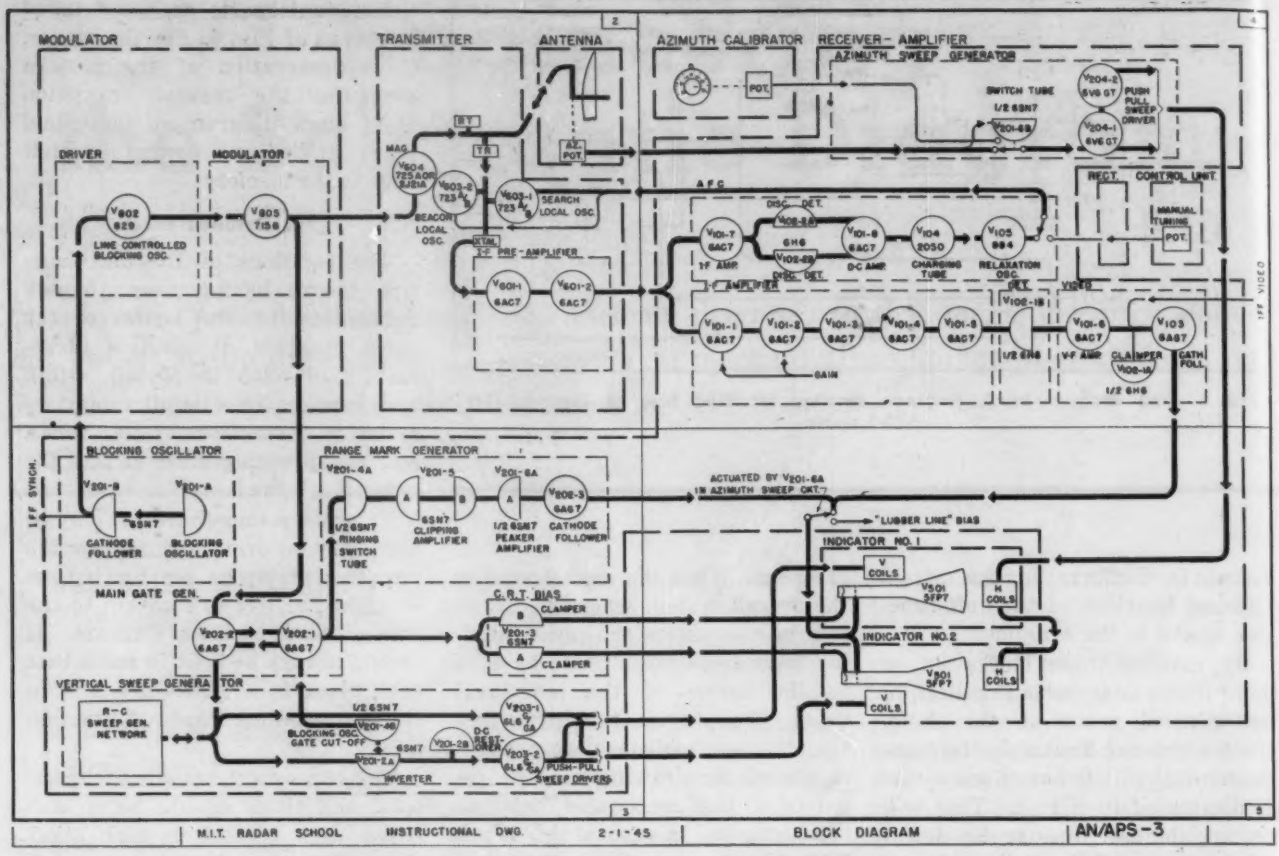

FIG. 3—Final block diagram of APS-3 radar, with helpful detail filled in. Arrangement in four quadrants permits comparison with the four schematic diagram sheets, one for each quadrant, that are drawn next

highest near the top, lowest toward the bottom.

Bridge circuits should be drawn to look like a bridge. If the plate impedance of a vacuum tube is part of an arm of the bridge, it should be drawn in one of the sides of the diamond and oriented to match. This will immediately assist the reader to understand what the designer expected the tube to do.

When networks might require the application of Thevenin's or Kirchhoff's principles for analysis, the link elements, meshes, and junctions should be drawn to stand slightly apart from other circuits and be arranged so that the appropriate principle is apparent.

Electrical symmetry as exemplified in balanced circuits should be expressed as graphical symmetry. Symmetry of general function should also be so shown where appropriate. It should be emphasized that graphical symmetry should not be employed for the sake of pictorial composition when no such real electrical symmetry exists.

Electrical similitude should be emphasized, when valid, by graphical similitude. A group of R-C chains, selectable by a switch, all similar in principle but differing only in time constant, should be grouped; all pairs of resistors should be placed at the same level and the attitudes of one R-C combination repeated for all. Once the reader has decided what one is for, he can plainly see that all fulfill the same purpose. Such an R-C group should stand apart from other similarly appearing R-C links whose function is not immediately related to them.

Where cables connect one outlined unit to another, the sides of such units should be arranged to be adjacent and the elements so arranged within that the cable can be shown as a family of straight wires, free of cross-overs, running between the units. Some cable wires will carry the chain-of-function flow, standing out boldly and becoming part of the general framework of the diagram.

Too often the simple circuitry of primary power distribution involving on-off switches, fuses, automatic overload cut-outs, interlocks, time delays, gate and battle switches, can become woven into a complex web of advanced wiremanship that would defy Maxwell himself, though he be armed with the finest of volt-ohmmeters. These primary circuits are usually set up sequentially: that is, the one most remote from the main fuses depends upon the functions of numerous devices preceding it. The diagram of this web should be drawn as branching chains of influence flowing across into rungs of a ladder whose rails are the two primary power leads. From the diagram it should be instantly apparent, without wire tracing, which units are controlled by a given switch and which chains of influence would be put out of commission by a blown fuse or open gate switch. The drawing should be deliberately set up so the man with the volt-ohmmeter can see immediately what

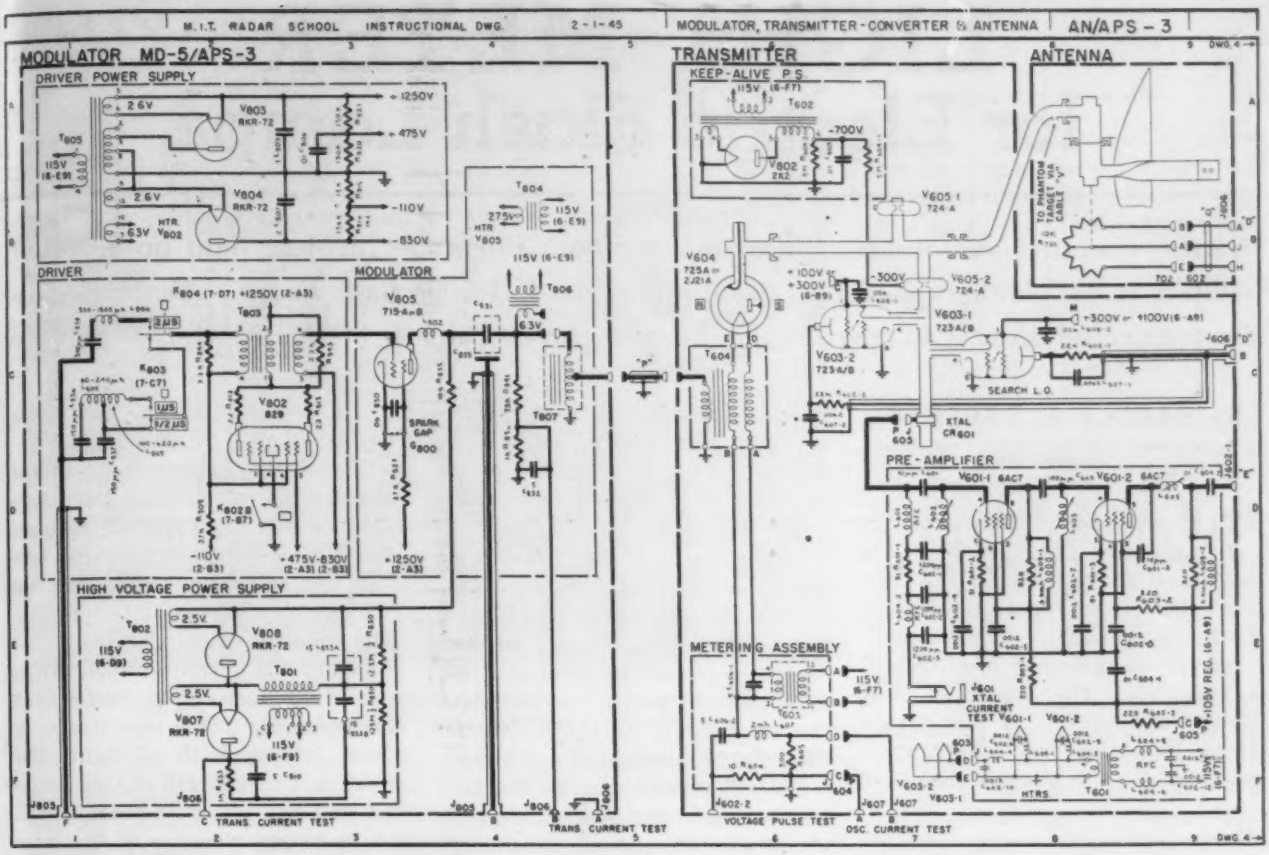

FIG. 4—Schematic diagram for upper left quadrant of Fig. 3, as drawn before standardization of symbols by ASA. Use of several weights of letters and lines improves effectiveness and eye appeal, but takes longer to draw

voltage or resistance he might normally expect to encounter in making a measurement at any point.

Designations and Markings

The schematic drawing should carry identification of every resistor, capacitor, tube, and switch. This means a designation (or part) number together with the circuit value or type number. It should make unnecessary the usual frequent and aggravating reference to the parts list.

All pin numbers on all tube sockets should be shown. All jacks, plugs, terminals, fanning strips and cables should carry their designations and actual numbers. All supply voltages should be shown where appropriate.

To eliminate many conventional leads from the drawing, a system of margin coordinates on each numbered page of the drawing makes it practical to show an arrow head on the end of a lead with a simple legend giving the drawing page number and coordinates where the other end of the lead may be picked up. This is used principally for plate supply voltage leads or similar common sources. Thus, in Fig. 4, drawing 2, the screen supply for the modulator tube has the legend + 1,250 V (2-A3). The 2 refers to the drawing sheet and A3 are the coordinates on drawing 2 where the screen supply source will be found.

Each control for adjustment, calibration or operation should be marked with the name it actually carries on the panel. This name (abbreviated) is usually enclosed in a box to designate that it is so marked.

It is desirable to designate by simple, appropriate symbols whether it is a screw-driver adjustment or a knob and whether it is accessible from the front panel or is within the chassis. Although the drawing examples printed herewith do not show the latter features, extensive and very helpful use was made of such designations in later drawings.

The several weights of letters and lines shown in the accompany-illustrations are the minimum found effective in providing the desired emphasis of flow and subordination of detail.

In the large amount of work done on drawings of this kind it has proved most satisfactory to standardize on 17" x 22" tracing cloth sheets for original ink drawings. This is a convenient scale for the draftsman and reduces to 8½" x 11" individual sheets in a 2 to 1 reduction. The examples shown here suffer unavoidably from a reduction somewhat more than this.

The authors wish to acknowledge the inestimable contributions of Richard L. Bliss of the MIT School of Architecture, who learned electronics for the sole purpose of producing the drawings described above and who wrestled with the fatiguing routines of countless redrawings to produce truly engineered schematics.

LIGHT METER
for Electric Flash Lamps

Battery-operated phototube-amplifier-meter circuit integrates incident light produced at subject to be photographed by capacitor-energized electric flash lamps. Meter is calibrated to read directly in aperture numbers for correct color or black-and-white exposures

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THE photoelectric light-integrating meter described here was developed for measuring the incident light from repeating electric-flash photographic light sources that are energized by discharge of a capacitor. The object of most light measurements of this nature is to determine the camera aperture, and for this purpose the meter can be calibrated to read directly in aperture numbers that will result in properly-exposed photographs for both color and black-and-white film.

The person most interested in the use of this meter is the one who is to take color photographs. He will place the meter at the subject and direct the phototube opening at the main light. A pushbutton will flash the key light or all the lights and the meter will indicate a given reading if the correct camera aperture for the type of film selected has been pre-set on the optical attenuator. The photographer can then adjust the camera aperture to the value indicated by the meter, or modify the distance to the key light to obtain some desired aperture.

As a next step, the fill-in light, background lights and spots can be measured and the light-to-subject spacing arranged so that the ratio of the key light to these others will produce the desired photographic effect.

A further use of the meter is to check the output of electric-flash lighting equipment, by comparing meter readings for standard and unknown lamps and power units. Also, the effectiveness and angular distribution of light from reflectors can be evaluated.

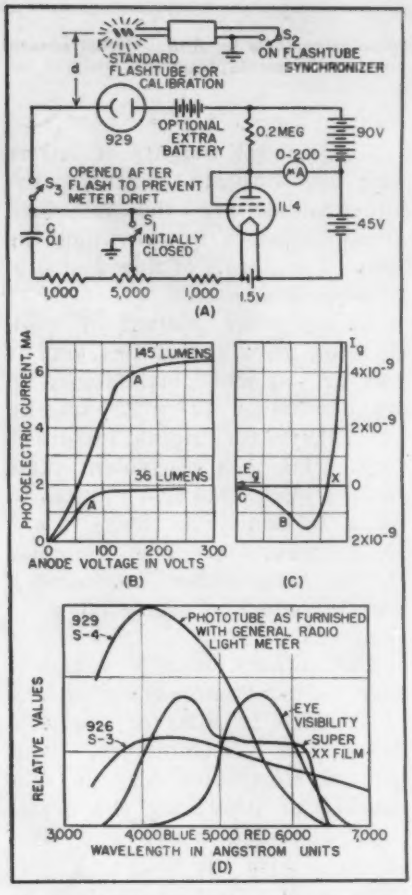


FIG. 1—Circuit and characteristic curves of photoelectric light-integrating meter for capacitor-discharge electric flash lamps

Design Data

The measurement of the quantity of light produced by a flash from an electric-flash lamp involves the integration of instantaneous values of light over the duration of the flash. A circuit that accomplishes this under certain conditions is given in Fig. 1A. The measurement of light requires that the phototube current and instantaneous light be proportional, so that $i = KF$, where K is a constant relating phototube current i and light flux F.

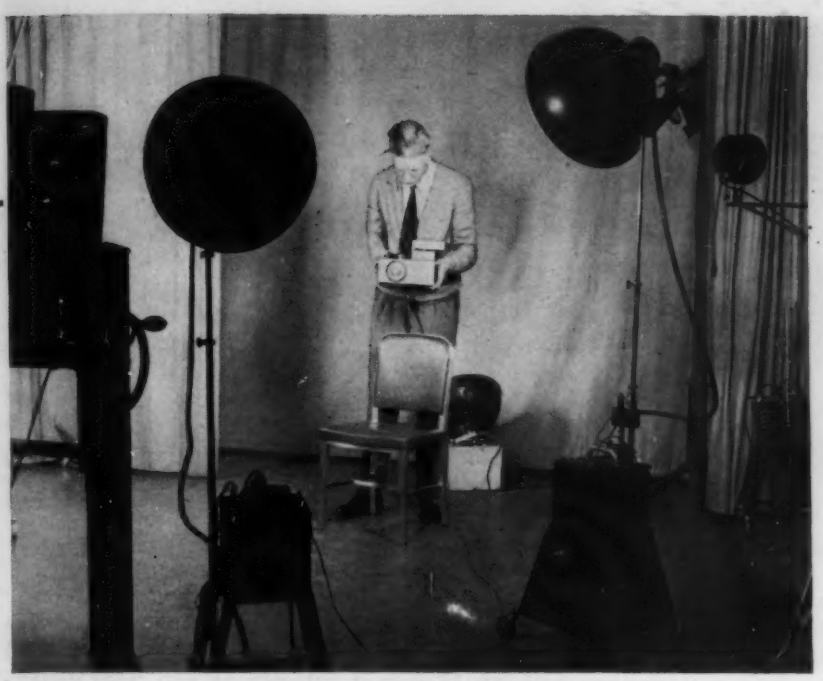
Figure 1B shows the general shape of the volt-ampere characteristics of an RCA Type 929 vacuum phototube with strong illumination. Note that the current and luminous flux can be proportional only for voltages above the knee (point A).

Should the instantaneous variation of luminous flux exceed that corresponding to the knee during a short, intense flash of light, the equation $i = KF$ will not be satisfied and the meter indication will not be a true measure of the integrated light. Gas-filled phototubes cannot be used since, because of the effects of the gas, the current may not be proportional to flux. The curves of Fig. 1B show that about 100 volts is required on this phototube if 36 lumens is the greatest instantaneous illumination that is to be experienced. For 145 lumens, the voltage should be about 200 volts. From this limited number of data it appears that the saturation current is approximately a function of the square of phototube voltage.

A voltage proportional to the integrated light and thereby proportional to exposure is obtained across an integrating capacitor C if the phototube current flows ino the capacitor. The voltage is

$$e_c = \frac{1}{C}\int_0^\infty i\,dt = \frac{K}{C}\int_0^\infty F\,dt \qquad (1)$$

A vacuum-tube voltmeter with an indicating meter M is used to record the voltage without discharging the capacitor at a rate which interferes with the reading of the meter after the flash. The drift of the indicating meter after a flash reading will depend upon the grid current of the vacuum tube, the leakage current of the phototube,



Light meter is held at position to be taken by subject and is aimed at flash lamp, which is tripped remotely by pushbutton on end of cord

and the leakage of the circuit. The size of capacitor C must be increased to such a value that the drift is inappreciable unless some method is provided to adjust the drift, such as grid current compensation.

In the practical design of an integrating light meter the capacitance for an uncompensated circuit is usually about 0.1 μf when the meter drift is limited to less than a full-scale deflection in about 30 seconds.

From the equation $i_c = C(de/dt)$, the time to drift to full scale, if the grid and leakage currents are assumed constant, can be given by $t_d = Ce_c/i_c$, where e_c is input voltage to produce a full-scale deflection, t_d is the time required for the meter to drift from zero to full scale, and i_c is the current that causes drift in the integrating capacitor C. Thus the drift time is a function of the grid and leakage currents and the integrating capacitor once an amplifier design has been selected.

The grid current curve of a typical three-electrode vacuum tube appears in Fig. 1C. For most tubes the crossover point X of zero grid current is about −1 volt with respect to the negative end of the cathode. It is inadvisable to operate on the right-hand side of the crossover point since the grid current increases rapidly due to electrons that arrive at the grid with energy obtained from thermal processes at the cathode. Positive ion currents are responsible for the negative slope of the grid current curve between the points B and C since the number of positive ions is directly a function of the plate current. To the left of point C the plate current is cut off and the tube serves no useful function. Therefore the portion of the characteristic that can be used falls between C and X.

Point C as well as the entire curve depends upon plate voltage. A plate voltage is selected that is as low as possible, but still ample to produce plate current that is several times that of the maximum reading of the meter. The usual practical value of grid bias is well to the left of point X for all operating conditions.

The type 1L4 tube connected as a triode with the screen and plate tied together can be used with 45 volts on the plate, a plate current of 0.5 ma and a grid bias of −1.3 volt. A 200-microampere meter is used as an indicator. Under this condition the grid current is less than 10^{-9} ampere for selected tubes that have been aged for two days with 90 volts on the plates.

Self-Bias Connection

Amplifiers with self-bias resistors have voltage calibrations that are relatively independent of the tube constants. This independence of calibration is gained at the expense of sensitivity in the conventional circuit design. However, for this special type of amplifier with a floating input capacitor, as used for light measurement, the advantages of self-bias can be gained without a loss of sensitivity. As long as the product of capacitance C and the voltage necessary for full-scale deflection e_c is constant, the light necessary for full-scale deflection of the meter and the drift time will not be changed. The drift time is also proportional to the same product.

A suitable design with degeneration by means of a cathode resistor is one that reduces the gain by a factor of five; this is provided by the circuit of Fig. 1. Such a design will decrease the influence of tube characteristics by a factor of about the same value.

Testing the Instrument

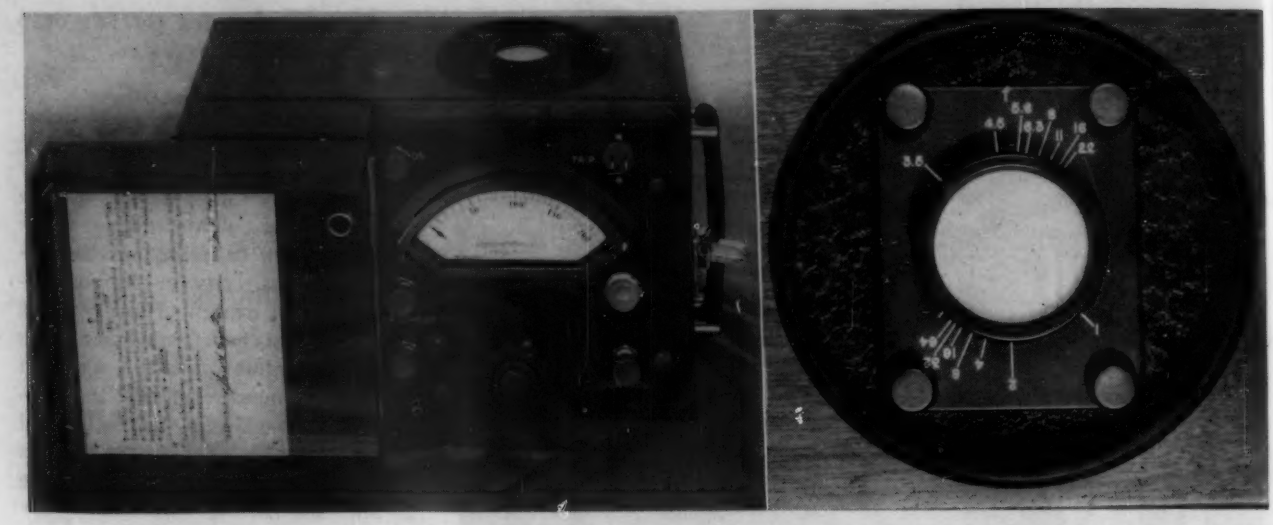
Should the phototube voltage be less than that required for saturation the meter will read low. A simple test of the meter, with any flashing light source of known duration, is to vary the phototube voltage and record the resultant meter reading. If the meter reading is constant as the voltage is increased, there is ample voltage on the phototube. The limiting phototube voltage can be found by decreasing the phototube voltage until the meters begin to drop.

If a flashtube with a shorter flash is used, but with the same quantity of light, the break will occur at a higher phototube voltage.

Shortest Allowable Flash

The duration of most flashtubes ranges from 50 to 1,000 microseconds. As a general rule, the duration is longer for the more powerful lamps.

The limiting time of flash can be calculated approximately as follows: Assume that the flash of light is of rectangular form providing F



Complete battery-operated photoelectric light-integrating meter as made by General Radio Co., and closeup of phototube aperture containing Polaroid attenuator

lumens on the phototube cathode for T seconds duration. The quantity of light is

$$Q = \int_0^T F\,dt = FT \qquad (2)$$

or

$$e_c = \frac{1}{C} KFT = \frac{i}{C} T \qquad (3)$$

The phototube current is KF amperes, and $i = Ce_c/T$. From this it can be seen that the peak current through the phototube is a direct function of the integrating capacitance and the voltage required for full scale on the deflecting meter. Likewise, the required phototube current for full-scale deflection increases inversely with change in duration of the flash. A short flash will require a larger phototube current and a higher phototube voltage if a full-scale reading without error is to result.

A phototube circuit with 100 volts on the 929 phototube and with a peak flux of 36 lumens will produce a photoelectric current of 1.7 ma, as shown by the lower curve of Fig. 1B. With $C = 0.1$ μf and $e_c = 2.5$ volt (sufficient for a full-scale deflection of a 200-microampere meter), $T = Ce_c/i = 147$ microseconds, assuming a rectangular pulse of light. The actual pulses of light from electric-flash tubes rise sharply to a peak and then decay with a form resembling an exponential.

With 200 volts on the phototube the current can be about four times greater and the time similarly decreases to 36 microseconds. By similar reasoning, a half-scale reading can be made with an 18-microsecond pulse with 200 volts on the phototube.

An approximate general expression for the necessary phototube voltage required to give an accurate integration of a rectangular pulse of light of duration T can be obtained if the phototube saturation current i is taken to be a squared function of the phototube voltage E. The expression is $i = AE^2$, where A is a constant. This current, when substituted for the integrator capacitor voltage previously given, results in the following expression for the required phototube voltage

$$E = \sqrt{Ce_c/AT} \qquad (4)$$

As a numerical example, the required voltage calculated for a one-microsecond flash is 1,150 volts. This might cause a flashover in the phototube. If it is necessary to measure microsecond pulses, a more sensitive amplifier or a smaller integrating capacitor should be used. Such a modification requires a smaller grid current in order to keep the meter drift time at a reasonable value. The phototube voltage becomes 240 if $e_c = 0.1$ volt and $C = 0.1$ μf. These are reasonable values that can be obtained with a two-stage amplifier with grid current compensation.

Some care is required in selecting a suitable integrating capacitor since some capacitors have leakage and others have absorption effects that are serious. It has been found that polystyrene and mica capacitors have very desirable characteristics. Certain types of oil capacitors can be used with success as integrating elements.

The light-meter calibration is made with a specific phototube (type 929) which is a vacuum-type tube with an S-4 surface. If other types are used, the calibration will not hold. The S-4 surface has a peak sensitivity in the blue portion of the spectrum, at 4,500 A. The sensitivity decreases from this peak to the cutoff value which is in the orange. Very little red light is measured. Thus the meter measures mainly the blue light. This is not a serious disadvantage since most photographic film, even the panchromatic types, also has a sensitivity peak in the blue.

For color photography the flash-tubes that are used are mainly filled with xenon gas at high pressure for high-efficiency use. The meter should then be calibrated experimentally with a xenon lamp under conditions that are known to produce a suitable color-photograph result. Fortunately xenon flash-tubes are of about the same color temperature regardless of the energy loading, and therefore the light meter can be used for comparison purposes with success even if only sensitive to blue light.

Figure 1D shows the spectral sensitivity of two types of photoelectric surfaces as well as the

standard eye visibility curve and film response. A different phototube, type 926 (S-3 surface), has a sensitivity curve that covers the entire visual range as well as some of the infrared, but has a lower overall sensitivity than the 929.

The Corning Glass Works can make on special order a filter composed of two kinds of glass that will correct the 926 phototube spectral characteristic to correspond to the visibility curve. A filter composed of glasses 3304 and 4784 gives a suitable combination. An accurate match can be made to any particular phototube at two wavelengths (6,400 and 4,800 A) by adjusting the thickness of the two glasses.

The phototube in the light meter will respond to the light from any kind of light source. However, the meter output cannot be expressed in lumen seconds per square foot unless the spectral distribution is the same as that of the xenon flashtube that is used for calibration. All xenon flashtubes, to a first approximation, have a comparable spectral distribution and therefore the meter readings can be given in terms of lumen seconds.

Maximum Meter Sensitivity

The example given previously (e_o = 2.5 volt, C = 0.1 μf) will have a maximum reading of the meter corresponding to 36 lumens for 147 microseconds when a phototube voltage of 100 volts is used. This reading corresponds to $36 \times 147 \times 10^{-6} = 0.0053$ lumen-second with a tungsten source having a color temperature of 2,850 Kelvin. Xenon lamps have an equivalent color temperature of from 6,000 to 9,000 and because of the proportionally greater blue light, require less than half as much visual light in lumen-seconds to produce the equivalent phototube current in the 929 phototube. For this reason a xenon flashtube will produce a full-scale reading of the meter with about 0.0026 lumen-second of incident light.

The projected area of a 929 phototube cathode is about 0.5 square inch, so the phototube cathode has a light density of about 0.005 lumen-second per square inch when used to measure the light from axenon flashtube. We will now calculate the distance from a standard flashtube that will give this deflection for calibration purposes. A standard FT-214 flashtube (General Electric Co.) flashed from 30 μf at 2,000 volts emits some 2,000 lumen-seconds and has an intensity I of 200 horizontal candlepower-seconds with a duration of about 150 microseconds. The number of lumen-seconds per square inch at a distance d in inches is $L = I/d^2 = 0.005$ lumen-second per square inch, from which $d = I/L = 200$ inches = 16.7 feet.

Calibration of the meter can be accomplished directly by this method, using a standard flashtube operated under specified conditions. Thus a full-scale meter reading corresponds to $U = 200/16.7^2 = 0.715$ lumen-seconds per sq ft.

The reading of incident phosage in lumen-seconds per square foot can likewise be calculated from $U = kRM$ lumen-seconds per square foot, where M is the meter reading, R is the polaroid attenuation ratio as read on the front of the meter, and k is a constant of the instrument. The light transmission of the uncrossed Polaroids at the 1 setting of the instrument is about 30 percent and this influences the value of k.

A diffusing disc is shown on the attenuator, which also acts as a calibrator to make the meter direct-reading in lumen seconds per square foot; for this case k equals 1. With the diffuser removed, the value of k for most instruments is 0.015 with a 200-microampere meter, with 200 as the full-scale meter reading.

The beam-candlepower-second output of a given flashtube and reflector combination is $kRMd^2$ or Ud^2, where d is the meter-lamp distance in feet.

Neutral-density filters can be used to extend the scale range. Thus a 1/10 transmission filter would give a multiplying factor of 10. Neutral-density filters are available in decimal, logarithmic and percentage steps.

The meter has an angular acceptance ratio depending upon the diffusion disc and other factors. With the disc, the meter reading decreases to half value when the meter is swung 25 degrees from the meter-lamp axis. This angle decreases to 15 or 20 degrees without the diffuser. Any type of diffuser can be used in the filter adapter ring on the instrument.

Determining Camera Apertures

Preliminary experiments show that about 100 incident lumen-seconds per square foot (U) are required to expose daylight Kodachrome properly with a CC15 filter at an aperture of f/3.5. The aperture f is then equal to $\sqrt{0.122U}$, where phosage U is in lumen-seconds per sq ft. Values of average incident light U required for various apertures are as follows:

Aperture f	Phosage U
1.0	7.85
1.5	18.5
2.0	32.6
2.5	50.8
3.5	100
4.5	165
5.6	256
6.3	326
8	520
11	986
16	2,080
22	3,940
32	8,380

As an example, suppose the lights are fixed and the meter is to be used to determine the aperture. Guess at an aperture such as f/3.5 and make a reading. If the meter reads 100, the guess was correct. If it reads 200, the light is double that needed at f/3.5. Therefore the aperture should be increased one stop to f/4.5. Likewise, if the meter reads 50, the correct stop is f/2.5.

Eventually tables of suitable values of incident lumen-seconds per square foot for all types of photographic emulsions and for different flash durations will be available from the film manufacturers.

The meter has an aperture scale on the Polaroid attenuator to read camera aperture directly. The aperture marks have been placed so that they correspond to a meter reading of $U = 100$ for the correct lighting condition for the indicated aperture with daylight Kodachrome. These readings require the calibrated diffusing disc on the attenuator that is furnished with the meter. This disc also makes the meter direct-reading in lumen-seconds per square foot.

Facsimile Modulator Tube

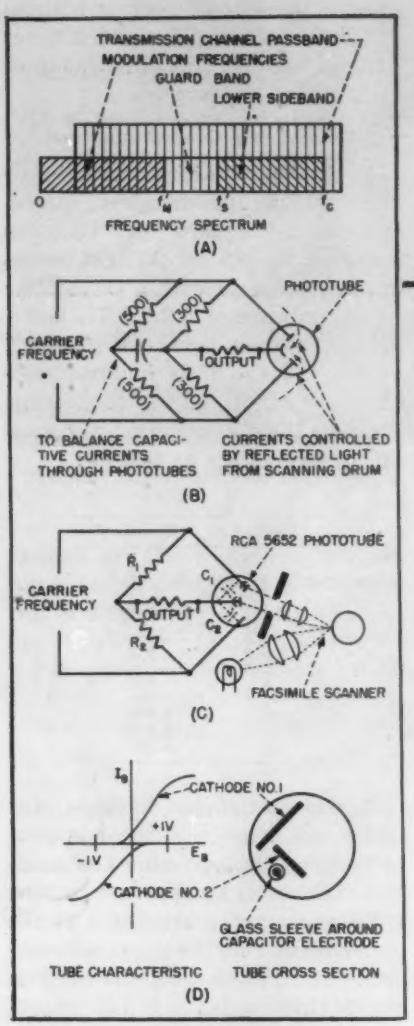


FIG. 1—Basic considerations in design of bridge modulator for facsimile

By J. R. SHONNARD

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HIGH RESOLUTION facsimile signals are transmitted over existing communication facilities by amplitude-modulated low-frequency carriers. A new type phototube and bridge modulator have been developed that enable light from the facsimile scanner to produce the modulation directly without generating frequencies that have to be eliminated by costly filters. The tube and circuit may simplify other systems in a similar manner.

Facsimile Transmission

Before describing the phototube and its action in the circuit, it is best to review the modulation problems that lead to its development. In many communication systems, facsimile being a typical example, the lowest modulation frequency is zero cps, corresponding in this case to a picture area of uniform density. The highest frequency is limited by what can be transmitted by the channel. Modulation currents as such cannot be transmitted over existing facilities because they are essentially interrupted d-c. To transmit them without introducing excessive distortion the channel would have to be polarized from transmitter to recorder thus requiring d-c amplifiers.

The solution to the problem has been to transmit the signal as an amplitude-modulated low-frequency carrier of frequency f_c. Under such condition the highest modulating frequency f_M' is limited to half the carrier frequency, assuming that filters with ideal cutoffs are available. Therefore the highest possible carrier should be used. In practice, the upper frequency limit is determined by the top of the channel passband. The carrier frequency is thus selected near this limit. Only the lower sideband of the amplitude-modulated carrier can then be transmitted, but this is all that is necessary for faithful reproduction and provides an efficient way to use the available channel. The manner in which these frequencies occupy the channel spectrum is shown in Fig. 1A.

The modulation frequencies f_M produce lower sideband frequencies f_s extending from the carrier f_c to the lowest sideband frequency $f_s' = f_c - f_M'$. When $f_M' = f_c/2$, $f_s' = f_M'$. If a higher modulation frequency is used the modulation band overlaps the lower sideband producing extraneous frequencies. Under such conditions filters cannot be used to prevent modulation frequencies from reaching the transmission circuit. If $f_s' = f_M'$, ideal filters could separate the modulation and sidebands and 50 percent of the transmission band would be used. Actually sufficient guard band must be left between modulation and sideband frequencies so that realizable filters can be used. If filters that do not have such sharp cutoffs as to introduce transient distortion are employed, the maximum use ratio of the channel is only 30 percent.

Phototube Modulator

The conventional type phototube bridge modulator shown in Fig. 1B produces both the modulation frequencies contained in the impinging light beam and the sideband frequencies of the modulated carrier in its output. The circuit is balanced for reactive and resistive currents. Light on the phototube upsets the resistive balance to produce the modulation.

When the RCA 5652 phototube, which has been designed for this service, is used, the output contains only the modulated carrier and sidebands. The signal can be connected directly to a conventional amplifier that is reasonably flat over its passband; filters are unnecessary. The phototube has two flat cathodes arranged at approximately right angles to each other. When both plates are illuminated, one acts as a cathode and the other as an anode, depending on the polarity of the

Phototube having two plates each acting alternately as cathode and anode simplifies bridge modulator. Because tube conducts alternately in one direction and then in the other, only desired modulated carrier and side bands appear across the output

potential applied between them. If the applied potential is alternating, equal current pulses flow in both directions with equal light on both plates. The average current is then zero. Even a flash of light for the duration of one cycle of the carrier causes equal but opposite pulses to flow so that the effective current remains zero up to modulating frequencies of half the carrier frequency. Contrasted to this action, the current flow in a conventional phototube in a modulator circuit is unidirectional.

As used in the modulator, the new phototube is a variable impedance, the two cathodes being connected as an arm of an a-c bridge. Capacitive current is balanced, preferably by an electrode built into the phototube and completely covered with a dielectric. The capacitance between this electrode and one cathode is made approximately equal to the capacitance between cathodes.

For modulation by this tube the bridge circuit can be arranged as in Fig. 1C. If no light reaches the tube and $R_1 = R_2$ and $C_1 = C_2$, there is no voltage output. As reflected light reaches the phototube, conduction takes place in the direction governed by the polarity of the carrier. Both electrodes are photoelectric and therefore act alternately as cathodes and as anodes.

The amplitude of the applied carrier is limited by saturation of the cathode current in this circuit. The phototube operates on the linear portion of its characteristic curve, shown in Fig. 1D, for a given range of light values. In the case of high definition facsimile the maximum light is in the order of 4×10^{-4} lumens. The elemental area of illumination at the scanning drum is about 5×10^{-6} square inches. The carrier potential applied to the bridge is about 0.7 rms volt. If the bridge is balanced with the light source off, when the light is turned on the output voltage will be undistorted modulated carrier proportional to the instantaneous light intensity reflected from the rotating scanning drum; only carrier and sidebands will be present.

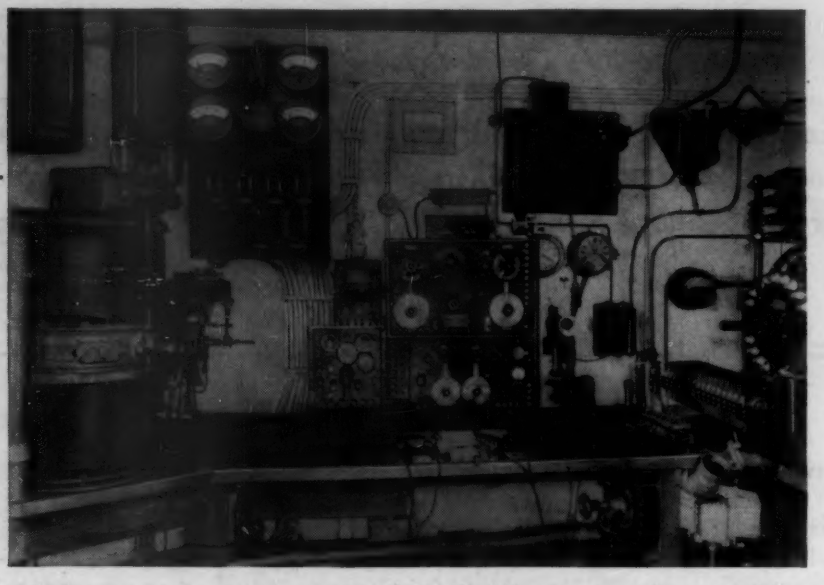
Operating Circuit and Tests

For convenience and ease of adjustment the circuit that is used has balancing controls. In addition, a diffusing plate is placed over the aperture to overcome two difficulties. First, a sharply focused image can cause uneven illumination of the two cathodes and thus produce occasional d-c keying components in the output. Second, the light beam passing through the aperture covers too small an area on the photocathodes for ease of adjustment when balancing the bridge to eliminate the modulation frequencies from the output, unless the optical system is very long. The diffusing plate defocuses the beam without sacrificing resolving power.

In operation, the output voltage varies from a maximum between 0.005 and 0.010 rms volt to a minimum controlled by the noise from the balanced bridge with the light off. The noise level of the bridge and the first stage of the amplifier is equivalent to 25 to 50 microvolts at the grid of the first stage. The load resistor, which also serves as the grid resistor of the first amplifier tube, can be from 1 to 20 megohms depending on the compromise that must be made between high sensitivity and stability against humidity, stray fields and input noise. The phototube noise does not seem to be a problem. The useful voltage ratio for light variations is therefore from 40 to 50 db.

When the scanner observes a 1.6-reflection density photographic black, the output rises about 10 db above the noise level. This level determines the minimum useful signal. When the scanner observes a bright white, the output rises an additional 30 to 35 db. However, such a range is beyond the capabilities of an average transmission channel. Therefore, after amplification, the signal is compressed to a range of about 20 db, within the limits of most channels.

Resolving power of any equipment with a given carrier frequency can be determined roughly by reducing the size of print being transmitted until the copy reproduced at the receiver is just illegible, assuming the receiver to be linear above the carrier frequency. A better but more complicated method is to select a type face and size that has a line width greater than is necessary to block light to the phototube. It is then certain that full interruption of the light to the phototube will be produced regardless of scanning velocity. Increasing the scanning velocity at both transmitter and receiver with a given carrier frequency will determine the maximum resolving power, and therefore the maximum usable modulation frequency for a given system. With the new phototube, 50-percent utilization of the channel can be realized and thus good resolution can be obtained.



Radio room of Army transport about 1918. The 5-kw arc transmitter is at left

Radio in the Merchant Marine

Survey of ship communications for message handling and safety of life at sea. Basic radio law and changing legal requirements are reviewed as background in the evolution of technical equipment to meet specifications. Current trends are analyzed

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HISTORICALLY, it was the maritime mobile service that first adopted commercial radio communication and demonstrated its value to the world. Radio has maintained a brilliant record in the saving of life and property at sea from a period more than a decade preceding that fateful night in 1912 when the distress call from the stricken *Titanic* dramatized its usefulness. But in spite of the impetus which this highly successful application gave to the radio industry during its infancy, technical progress in the marine field has been along conservative lines following, rather than leading, shore developments.

Views expressed in this article are the author's and do not necessarily represent those of the U. S. Maritime Service.

The first shipboard radio installations (circa 1901) utilized the discharge of a large spark coil across a straight gap into a tuned antenna system to radiate energy. A coherer, or rudimentary form of a multiple-point-contact rectifier, connected to an inker was used to record the received signals. Thus, it is to be noted that the first shipboard radio installations employed automatic recording and visual presentation of information! Within a short time the oscillatory discharge of a capacitor across a synchronous or quenched gap was adopted as an improved method of setting up oscillations in a large antenna system. Radio energy in the form of broad, highly damped waves, usually modulated at a convenient audio frequency, was radiated at frequencies in the order of 100 to 200 kilocycles. The received signal was demodulated by a magnetic detector. A significant improvement in receiver effectiveness was realized when the unilateral characteristic of mineral crystals was discovered and applied to signal rectification. Although some voltage gain was obtained from the rather low-Q tuned antenna primary and secondary circuits, the audio component effective in the magnetic-type reproducer was low. Range, even under conditions of moderate signal-to-noise ratio, was restricted and reliability of both receiver and transmitter not always of the highest order.

An improvement in system selectivity, increased range, lower antenna insulation requirements, and better signal note were some of the advantages gained through the introduction of the Poulsen arc type of continuous wave transmitter prior to World War I. The arc oscillator, however, was limited by

Typical shipboard installation of distributed type. Shown from left to right are the main transmitter, coil rack, emergency crystal receiver, intermediate and high-frequency receiver, high-frequency transmitter, and emergency transmitter

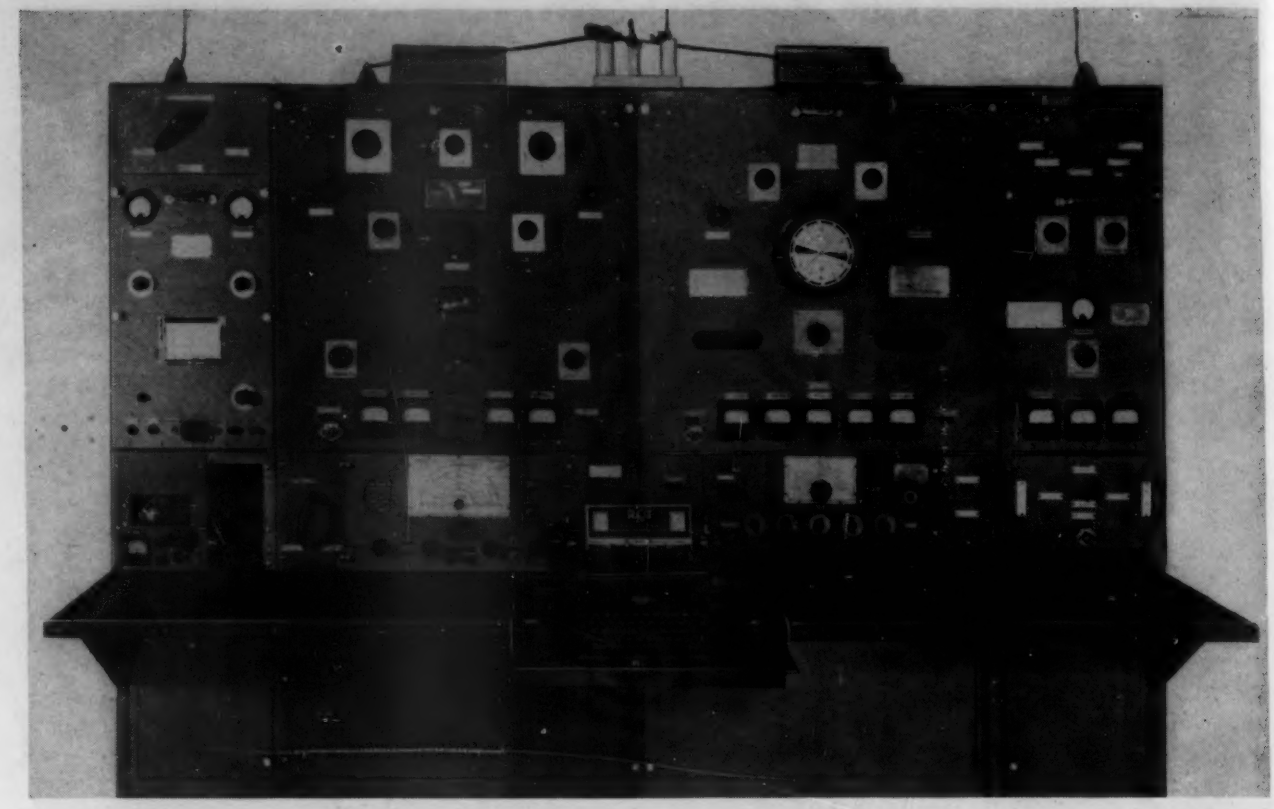
an inherent inefficiency to wavelengths longer than 1,000 meters (300 kc) and found its most useful application on wavelengths as high as 18,000 meters (17 kc). Rapid extension of the vacuum-tube oscillator to marine use and unsuitability for radiophone (A3) modulation were the important contributing factors to the eventual obsolescence of the arc transmitter. Nevertheless, standard 2-kw arcs remained as supplementary equipment on many ships throughout the 1930's and high-power installations of several hundred kilowatts were used in commercial and government coastal and transoceanic stations for many years.

Although the spark, arc, Alexanderson alternator (for land stations), and vacuum tube were concurrently or successively employed as oscillators during the three decades ending in 1930, the superiority of the tube eventually forced its acceptance by the marine industry. Early tube transmitters were usually of the converted spark type; that is, the oscillatory circuit of the shipboard spark equipment was replaced by one or two electron tubes with appropriate changes in circuit and power supply. Primary and secondary tuned circuits were left intact. Either c-w (A1) or tone modulated c-w (A2) emission was provided. Later tube equipments were designed especially for marine use. Some form of master-oscillator power-amplifier lineup furnished a choice of several working frequencies centering around the two international marine calling frequencies of 143 and 500 kc.

Improvements

During the period 1930–40 the replacement of early v-t transmitters by improved types incorporating crystal control, and the almost complete disappearance of arc and spark equipment occurred. Tuned-radio-frequency and superheterodyne receivers, designed for exclusive marine application, were adopted as standard. However, many merchant ships did not discard obsolete equipment until the late 1930's.

Other innovations in this decade were: (1) the rapid expansion of high-frequency communication facilities and the production of several types of well-designed marine transmitters for this work; (2) the increasing use of low-powered marine radiotelephone, particularly on the smaller vessels and communications involving safety or ship's business; (3) the mandatory installation of an automatic alarm, capable of giving visual and audible indication of impending distress or safety information, on all merchant



Typical packaged shipboard installation including automatic alarm (with keyer unit), high-frequency transmitter and receiver, intermediate-frequency transmitter and receiver, emergency transmitter, antenna switch, and charging panel. Motor generators are in lower section

ships over 1,600 tons where a continuous radio watch is not feasible; (4) the requirement for a battery-operated transmitter-receiver unit in motor lifeboats of certain classes of passenger vessels to reduce the hazard involved in ship abandonment.

Perhaps the most outstanding advance during the recent war was the development and production of the packaged shipboard radio station; that is, one unit containing three v-t transmitters, three receivers, automatic alarm, main and emergency power motor-generator sets, and all switching and control circuits. This package could be disassembled for handling and reassembled aboard the ship. Installation time was reduced from days to hours.

Hand-cranked, portable and semi-portable lifeboat transceivers, high-frequency facilities on nearly every U. S. ocean-going vessel, and a keen but discriminating interest in the value of new electronic navigational aids were other evidences that post-war applications of radio in the marine industry would expand. Thus the modern shipboard installation, the mobile end of the communications loop, is the end product of a 47-year old sporadic evolution and includes most of the technological advances made during the pre-war and wartime years.

Shipboard Radio Station

Every ocean-going passenger vessel and cargo vessel of 1,600 tons or over (certain government vessels and ships of the armed forces excluded) must have, upon leaving any U. S. port, an efficient, properly licensed radio installation in operating condition and manned by competent operators. Similar requirements are enforced by the administrations of other maritime nations. A continuous radio watch must be maintained at all times the vessel is being navigated outside harbors or ports. However, cargo vessels in lieu of additional operators may employ the automatic alarm device to monitor the safety and distress frequency (500 kc) during periods when the operator is off duty .

The minimum prerequisites for an efficient radio installation, aboard compulsorily equipped vessels, are specifically fixed by law. However, equipment design, provided certain essential performance is assured, is not specified except in cases where the use of obsolete techniques would cause undue interference to other services.

Each shipboard radio station must have: (1) main transmitter and receiver; (2) emergency transmitter and receiver; (3) emergency source of primary power independent of ship supply, capable of 6 hours continuous service; (4) other ancillary equipment contributing to effiiciency, such as a clock, and bridge communication. A normal range of 200 miles is required for the main transmitter and 100 miles for the emergency. Although at one time the low-frequency band between 100 and 200 kc carried the larger part of message traffic in the maritime mobile service, today nearly all work is done on medium or high frequencies. Most shipboard stations provide several working frequencies in the band between 350 and 515 kc, inclusive. The international

calling and distress frequency of 500 kc is used to make initial contact. Where supplementary high frequency is installed, it must comply with statutory regulations as to performance and use.

Regulatory performance specifications for marine radio equipment are not difficult to meet. There are, however, special considerations incurred by the stringent conditions of marine service. Ruggedness, compactness, part-replacement accessibility and protection against moisture and spray are some of the essential construction features. Efficient, well-standardized circuitry capable of easy and stable adjustment must be used throughout. Reliability must be of the highest order. It is necessary that operating controls be kept to the minimum consistent with good performance and that such controls be arranged conveniently. Provision for rapid one-control frequency shifting, simplified tuning, A1 or A2 emission at will of operator, use of 110 volts d-c as a primary power supply, or 12-volt storage batteries as an alternate emergency source, optional use of crystal control on medium and high-frequency transmitters, and a break-in system that will permit the operator to receive during keying intervals are features included in modern marine radio equipment.

Main and Emergency Transmitters

Power output of modern shipboard transmitters ranges from 50 watts for the emergency set to 500 watts for the main, medium-frequency equipment. Average power outputs of 150 to 200 watts are typical. From five to eight working and calling frequencies within the band from 350 to 515 kc are provided. Shifting frequency is accomplished rapidly by a ganged switch and antenna retuning.

The oscillator is conventional and usually has eight pretuned iron-core circuits, or ganged tapped inductances for easy switching. Provision for crystal control on all or any one of the frequencies can be obtained by substitution of appropriate crystal for a removable input capacitor. An alternative mopa lineup uses a self-excited oscillator, buffer, and paralleled-tube power amplifier. Antenna loading and tuning is accomplished typically by means of a tapped variometer. Plate modulation for A2 emission at 500 to 1,000 cycles originates in the power-supply motor generator which also supplies a high d-c voltage, or a low a-c that is increased and rectified for the plates.

Special precautions are taken to suppress harmonics and parasitics by complete shielding, oscillator-amplifier isolation, and r-f grid isolation. Primary, or some form of grid keying is used for carrier interruption in telegraphy.

Equipment Characteristics

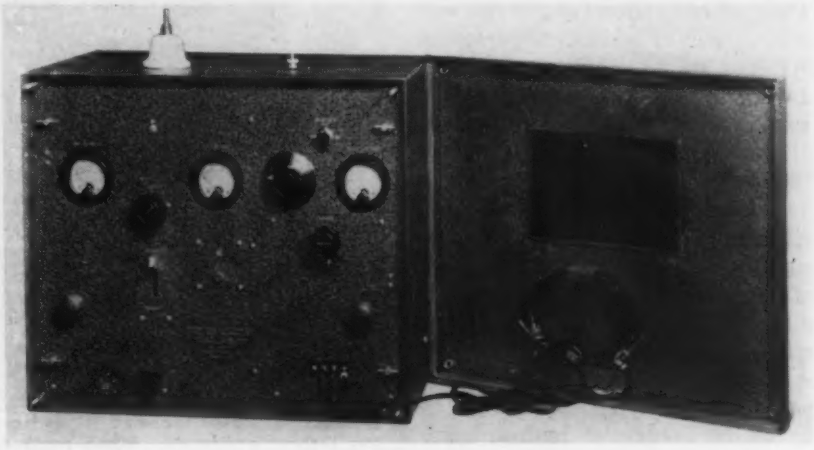
The emergency transmitter, as an independent unit, has an output power of about 50 watts into a standard shipboard antenna, or single-wire (against ground) radiator of approximately one-quarter wavelength, end or center-fed. Antenna characteristics vary between 500 to 1,500 $\mu\mu$f and 4 to 10 ohms. Modulated c-w (A2 emission) often due to raw a-c on plates, is frequently used. All power for the emergency transmitter is supplied from storage batteries through a motor-generator set of appropriate rating. Some main transmitters are so designed that they may be operated on reduced power from batteries, thus serving as emergency equipment.

Well-designed, rugged, dependable high-frequency transmitting equipment, specially built for shipboard use, is presently available. Power outputs of 150 to 200 watts, choice of A1 or A2 emission, provision for optional master oscillator or crystal control of eight frequency bands in the region 4.14 to 22.14 mc, are features of this equipment. Additionally, several working frequencies are included in each band. A stability percentage of ± 0.05 for master oscillator, or ± 0.02 for crystal oscillator is readily maintained under widely varying operating conditions. Oscillator circuitry is conventional. However, a form of temperature compensation is used by one manufacturer to insure the stability of a self-excited type. Convenient, rapid resetting of oscillator and doubler controls is provided for facile operation. Simultaneous cathode or grid-block keying of all tubes, and the use of the beam-power tubes in the power amplifiers is almost standard. For economy it is necessary that the high-frequency and main transmitters use the same motor generator through a suitable switching arrangement which permits alternate, but not simultaneous, operation.

Marine Radio Receiver

The receiver is a vital complement to the shipboard installation. A typical station includes three or four such adjuncts: (1) main receiver for the vlf, l-f, and m-f regions; (2) emergency receiver for the medium frequencies; (3) high-frequency receiver. For a standby watch on 500 kc while working on another medium frequency, an additional set is sometimes used.

The main receiver, although of straightforward design and construction, has special features for



Transmitter-receiver used in motor lifeboats carried by passenger vessels

marine radiotelegraph application. The trf type with regenerative detector is standard in the marine medium band. Band switching, or plug-in coils, for substantially continuous coverage from 16 to 600 kc gives considerable versatility. One or two stages of r-f, a regenerative detector, and two stages of audio amplification is a lineup commonly used. Designed primarily for reception of A1 or A2 emission, bandwidth considerations permit high gain and selectivity per stage. Response to modulated signals is still further improved in a receiver of one manufacturer by employing audio transformers peaked in the 500 to 1,000-cps region. A storage battery for heater supply and dry batteries for plates make the main receiver independent of the ship's power line.

The emergency receiver is a crystal-rectifier type as required by law. It covers a range from 350 to 515 kc and will respond to A2 or type-B (spark) emission.

Although special high-frequency receivers have been built for shipboard service, they possess few, if any, points of superiority over any standard, high-quality communications set. Generally, they use the superheterodyne principle and are engineered for ruggedness, reliability, and compactness rather than maximum performance and flexibility.

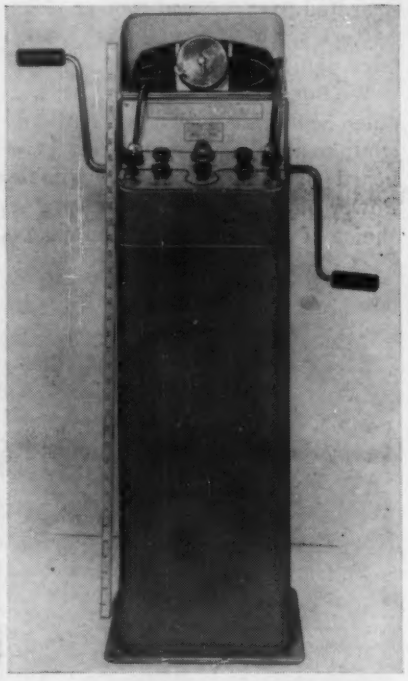
Automatic Alarm

Radio laws of the U. S. require that every ocean-going passenger vessel and every ocean-going cargo vessel of 1,600 tons or over shall maintain a continuous radio watch while at sea. However, cargo vessels, in lieu of additional personnel may use an automatic alarm device during the time operator is not on watch to guard the international distress and safety frequency of 500 kc. The automatic device must be capable of responding exclusively to an international alarm signal consisting of twelve dashes of four seconds length, spaced one second apart. To actuate, a minimum of 500 μv at the receiver input is specified. The alarm signal must precede all distress calls and may be used for urgent hydrographic or meteorological broadcasts.

Automatic alarms in use on U. S. ships are of two general types: one employs a superheterodyne receiver with an electronic selector; the other uses a sensitive trf receiver with a square-law detector and mechanical selector. Both instruments give audible indication when a true alarm signal is received and audible or visual notice or both when the alarm becomes inoperative owing to circuit failure or unusual external noise or interference conditions. Variable receiver gain permits a setting of sensitivity within the range 200 to 50,000 μv, thus allowing optimum adjustment for prevailing noise conditions. One equipment has auxiliary contacts that key the main transmitter to send out an alarm signal. A very recent development is an alarm responding directly to a specific ship's call letters or to an SOS call, thus expediting more immediate action in emergencies. Very few ships, however, are equipped with this device.

Lifeboat Radio Installation

International regulations make it mandatory that ocean-going passenger vessels maintain a complete radiotelegraph installation in one motor lifeboat where the number of lifeboats exceeds 13 and two such installations where the number exceeds 19.



A balloon-supported antenna is used on this lifeboat equipment. When cranked it automatically sends out SOS

The lifeboat transmitter and receiver unit are packaged together and mounted rigidly within a protective housing, usually in the bow. A fixed frequency of 500 kc is determined by a Colpitts oscillator arranged in a self-rectified, full-wave circuit. Modulation at 1,000 or 1,600 cps for A2 emission is obtained from a dynamotor of 110-volt, 500 or 800-cycle output. The primary source of transmitter plate and all filament power is two 12-volt, high capacity storage batteries; receiver plate voltage being furnished by dry batteries. An antenna of approximately 50 feet long, supported on collapsible masts gives a minimum reliable range of 50 miles. Power capacity must be such as to permit continuous operation for 4 hours.

Another type of lifeboat transmitter, an outgrowth of the Gibson Girl unit used in sea-air rescue work during the war, is frequently seen on merchant ships now. This equipment may be portable or semiportable and often incorporates a signalling facility only. Power is supplied by a hand-cranked generator integral with the equipment. Although the regulations requiring the installation of this device have been suspended, many merchant ships carry one or more as a means of extending the signalling area of a lifeboat.

Marine Radiotelephone

An increase in the convenience and economy in ship-to-shore, shore-to-ship, and intership communication has been effected through the establishment of medium-range marine radiotelephone networks. On the ten available frequencies in the 2-to-3 mc region a vast amount of information is exchanged. Through complementary coastal harbor stations connection can be made into the land-line telephone system.

Although certain large passenger vessels have complete facilities for long-distance radiotelephone communication open to public correspondence, equipment on most vessels is limited in range to coastal waters within coverage of harbor

stations. Smaller vessels, such as tugs, yachts, fishing boats, pilot boats, or those whose routes do not justify the expense of a radio telegraph station, have found the marine radiotelephone an invaluable aid to piloting or in transacting ship business.

Shipboard radiotelephone equipment, in addition to meeting the standard requirements of ruggedness, compactness, operational simplicity, and weatherproofing has, in its highest development, several features which increase its convenience and effectiveness. Since it is ordinarily installed on the bridge or in a chart room, it is operated by nontechnical personnel.

Crystal control on all frequencies is standard. A change in carrier frequency is accomplished by one switch and antenna retuning. A choice of the method of carrier interruption (for listening-in purposes) can be made by an operator using a button on his handset which can be released for listening, or automatic operation of a Vodas relay actuated by speech air pressure on handset transmitter diaphragm.

The radio receiver allows selection of pretuned, spot frequencies corresponding to transmitter settings. An automatic selective ringer can be installed to permit signalling of an individual ship by transmission of coded impulses from harbor stations. Separate control units for operation of equipment on a preset frequency from a remote shipboard position can be furnished.

The marine radiotelephone is invaluable in cases of distress. The Coast Guard maintains a listening watch on 2,670 kc on the Great Lakes and the coasts.

A postwar development of great significance is the growing popularity of f-m radiotelephone in the 157 and 162-mc bands. Use of certain frequencies in this region in conjunction with harbor-approach radar is expected to facilitate movement of traffic in high-density areas.

Basic Radio Law

World-wide regulation of radio communications in the maritime mobile service is based on the

Modern radiotelephone for marine use in pilot or chart room

Articles of the Convention for the Safety of Life at Sea, London, 1929, and the International Telecommunications Convention of Madrid, 1932, with annexed Radio Regulations. Except for the Radio Regulations, the United States is signatory to both these agreements. The recent Telecommunications Conference at Atlantic City, under auspices of the International Telecommunications Union, revised many extant regulations and made certain frequency re-allocations.

Statutory supervision of all communications in the United States is pursued under authority of the Communications Act of 1934 which created the Federal Communications Commission. As amended in 1937, this Act includes provisions of the Safety Convention for ship radiotelegraph stations.

Business Administration

Coincident with the development of marine mobile communications there has been a comparable growth of commercial companies specializing in the administration of the technical, legal, and business aspects of marine radio. In the United States four of the larger radio service companies, Tropical Radio & Telegraph, Radiomarine Corporation of America, MacKay Radio & Telegraph, and Globe Wireless, Inc., maintain extensive facilities for servicing and operating radiotelegraph and telegraph stations ashore and afloat.

Many steamship companies maintain their own radio organizations.

Today, for the ships of all nations, there exists a standardized, world-wide, radiotelegraph network made up of many systems but coordinated by the various administrations into a well-integrated, highly cooperative facility. There are few places on the high seas where a merchant ship need remain out of touch with its home port for more than a few hours at a time. However, since there can be no lessening in efforts to improve safety of life and property at sea, expedite ships' business, or improve public convenience in communications, progress in the marine radio field will continue.

Future Trends

Certain trends are already discernible; the next decade should see the following adjuncts widely accepted:

(1) Universal adoption of crystal control on all working frequencies of high and medium-frequency equipment.

(2) Replacement of many distributed-type shipboard radio stations by packaged, one-unit installations.

(3) Widespread use of some form of call-signal and SOS-responder device for supplementary watch-standing on all merchant ships.

(4) Greater use of the marine radiotelephone, particularly the vhf f-m type. Extension of present a-m radiotelephone ranges and use of vhf f-m in conjunction with navigational aids.

(5) Increased popularity of high-frequency bands for normal ship-radio traffic.

(6) Installation of radio facsimile on many passenger vessels.

(7) Limited use of television for public entertainment on the larger passenger vessels.

(8) Closer coordination of radio communication facilities, on shore and aboard ship, with sea and air safety and rescue work and with radio or electronic navigational systems.

The author wishes to thank the Radiomarine Corporation of America, 75 Varick Street, N. Y., and the MacKay Radio & Telegraph Co., Inc., Marine Division, 345 Hudson Street, N. Y., for supplying photographs accompanying this article.

Soldering

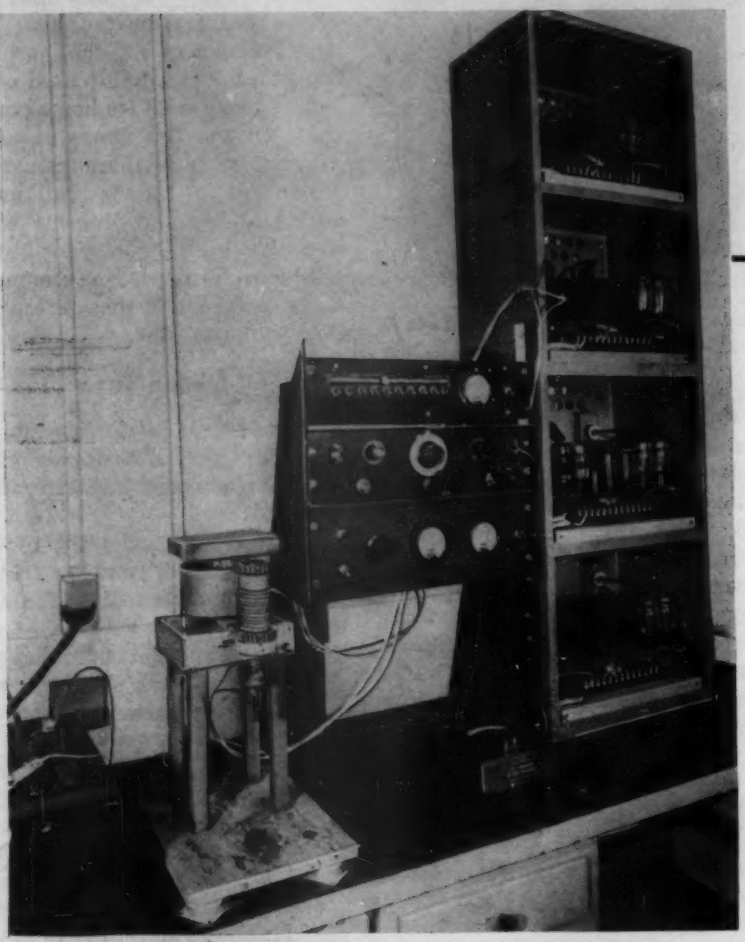


FIG. 1 — Experimental sonodizing setup. Left to right: 24-volt polarizing battery; magnetostriction transducer and soldering iron; unit containing oscillator, loading capacitors, and controls; four 50-watt amplifiers

THE TINNING of aluminum alloys presents problems tending to limit applications of soldering. Experiments indicate that some of these problems can be solved by vibrating solder at an ultrasonic rate while applying it to the work.[1] By this method the oxide coating is disrupted and alloying of the metals occurs before re-oxidation of the aluminum can take place.

The tinning of aluminum and its alloys through the application of magnetostrictive forces to a soldering iron is called sonodizing. Although sonodizing eliminates the use of a flux, if wide enough differences of surface potential exist between the metallic boundaries corrosion susceptibility exists and precautions must be taken commensurate with the conditions of exposure.

Transducer Selection

In order to establish satisfactory procedures for fluxless tinning, it was first necessary to select a vibration generator that could be readily modified to serve as a soldering iron. Selection of suitable equipment required analysis of the characteristics of several types of

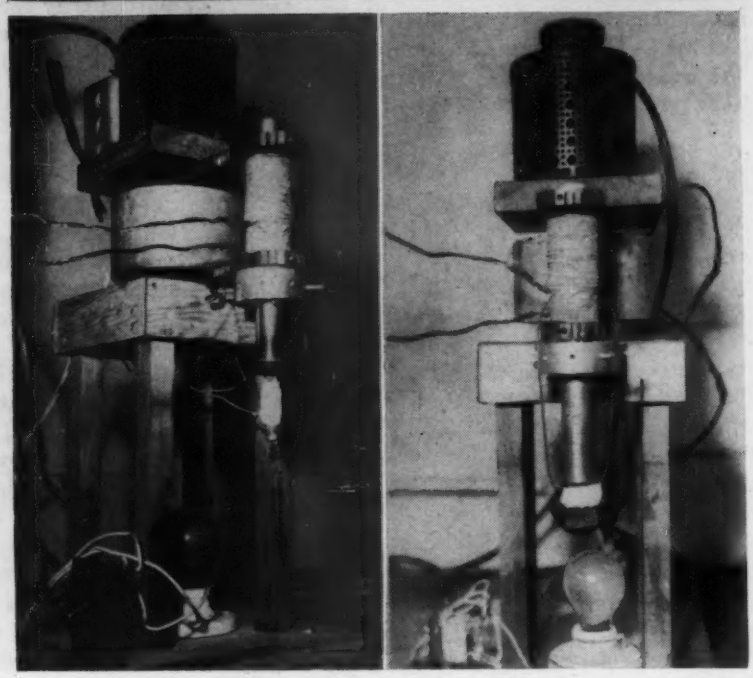


FIG. 2—Magnetostriction transducer with solid tinning tip and (right) with brush-type tip

Aluminum Alloys

Work is accomplished experimentally by vibrating the iron tip at an ultrasonic frequency by means of a vacuum-tube driven magnetostriction oscillator, to remove surface oxidation. Method is also applicable to stainless steel, chromium-plated and other hard-to-solder surfaces

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existing generators. The four types considered were: (1) magnetostriction, (2) electromagnetic, (3) gas, and (4) quartz crystal.

The deciding factor which influenced the selection of the magnetostriction unit was the ease with which the magnetostrictive element could be modified and equipped with a suitable tip. Such a transducer can, in fact, be fabricated so that the vibrating element itself is capable of withstanding direct immersion in molten metals and can be used directly as a soldering iron.

Transducer Characteristics

A magnetostriction generator of the type described by Pierce[2] has an effective frequency range of 1 to 50 kc. Amplitudes of 0.0001 to approximately 0.001 cm, which is the rupture point of nickel, can be obtained. Power up to 10,000 watts may be used. Less than 15 watts acoustic output is impractical where mechanical vibration is the objective. Transducer efficiency, which is the measure of coil output available as mechanical power or acoustic energy, seldom exceeds 15 percent. Operating temperature of the magnetostrictive tube within the coil is limited by the Curie point of the metal (300 F for Invar), but tip temperature of 800 F can be maintained for short intervals.

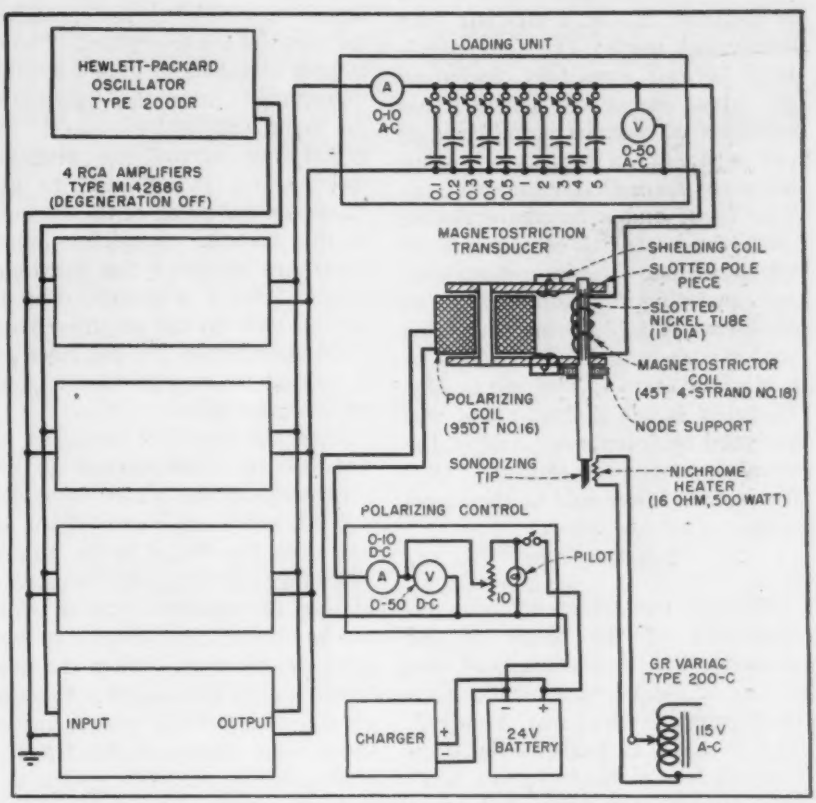

Diagram showing setup for tinning aluminum alloys. A switch (not shown) permits paralleling of 4, 7.5 or 15-ohm amplifier taps

The electromagnetic generator[3] is simpler and less costly than the magnetostrictor, but it is applicable mainly to low-frequency work with large volumes of fluid on a continuous basis. Similarly, a generator such as the Galton whistle[4] has some desirable features but it has a transducer efficiency of only 5 percent and is not as readily con-

FIG. 3 — Photomicrograph showing (bottom) alloy, aluminum cladding, and (top) solder

trolled as electronic devices. Again, the quartz-crystal oscillator is suitable for work requiring precise control, but unsuited at present to sudden temperature changes required in fluxless soldering. Fracture of the crystal is likely to occur.

The magnetostriction generator constructed by the authors with the assistance of Richard W. Powell of Lockheed, and Bodine Sound Drive, is pictured in Fig. 1 and has four component parts: (1) four paralleled 50-watt amplifiers, including an output meter and a switch for selection of various amplifier output taps; (2) a capacitor loading unit; (3) an oscillator tunable from 7 to 70 kc and a magnetostriction unit, the essential components of which include the magnetostrictor coil consisting of a helix of 45 turns of 4-strand no. 18 Formex-insulated copper wire wound in two layers on a Micarta frame. The coil is 3¼ × 1¼-inches inside diameter and was designed to operate one-half of the metal transducer element, thus freeing the lower half of the nickel tube.

Polarizing Coil

Because magnetostriction is independent of the sense of the magnetic field, a polarizing coil consisting of 950 turns of no. 16 insulated copper wire was required. The solenoid is mounted between two soft iron plates to form a magnetic circuit. The arms of the pole pieces are shielded by wrapping with copper to prevent interaction between the magnetostrictor and polarizing coil.

The nickel tube, supplied by the International Nickel Co., is 9 inches long, 1 inch outside diameter, and has a 1/32-inch wall thickness. Nine longitudinal slots 1/32 inch long were cut in the tube along the section enclosed in the energizing helix to reduce heating. The soldering tip consists of a ¼-inch stainless-steel rod, 4 inches long, silver soldered to the end of the nickel tube. A Nichrome heater coil is wound on a tube which maintains a loose sliding fit on the tip so that unnecessary mechanical loading is avoided.

The transducer is pictured in Fig. 2. The oscillator helix is mounted so as to cover one half of the transducer element. Iron arms enclosing the polarizing coil support both units. The magnetostrictor tube is supported at its center of mass in the dural holder shown in Fig. 2. The control equipment is mounted in two separate racks (Fig. 1).

Equipment Operation

To operate the system the power-amplifier, oscillator and polarizer-coil circuits are energized. The oscillator is tuned to give maximum vibrational intensity, activating the metal tube at resonance. The capacitance across the magnetostrictor coil is adjusted to give maximum deflection of the ammeter in this circuit. Amplifier impedances are adjusted for maximum output. Power is controlled by adjusting gain on the amplifier bank. Field strength of the polarizer coil is altered to give maximum magnetostrictive effect.

After the circuit is stabilized, the Variac is set to give proper tip temperature and the solder is applied and allowed to flow around the tip and onto the metal to be tinned. The operation produces an intense hissing and chattering noise which can be used by the operator to gage working efficiency. When the work under the tip area reaches the temperature of melting solder, two or three rapid passes of the tip generally produce satisfactory tinning.

As the metal surface does not ordinarily need cleaning, pre-etching or fluxing, corrosion is not a factor in the operation. An iron-wire brush tip was found to work well in some instances, with the added advantage that it more readily reaches inaccessible areas, scaled spots and scratches. Goggles and respirator are worn by the operator as the tendency of the brush or tip to throw metal constitutes a hazard.

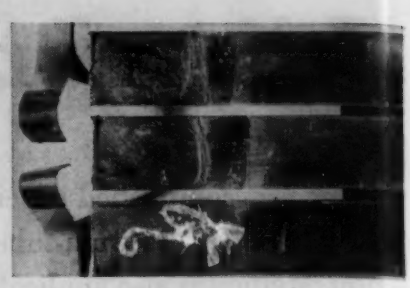

FIG. 4—Tinned dural panels

With the apparatus operating at 8 kc, tests have been made on aluminum and its alloys, notably 25ST and 75ST, as well as stainless steel, chromium-plated surfaces and anodized and dyed aluminum. Typical results are shown in Fig. 3 and 4.

Stainless steel tinned easily when a small amount of cadmium was added to the solder as a wetting agent. The same was true with chromium-plated surfaces. Phenolic strips were metallized with zinc, lead, cadmium and aluminum. Castolin eutectic 19B solder was used. Anodized and dyed aluminum tinned satisfactorily, but required a longer time than bare alloy surfaces. Ferrous metals such as 1010 and 4130 steel do not tin readily, requiring greater energy output and greater solder wettability. Aluminum aircraft-generator cable tips and lugs were tinned and then sweated together, resulting in very low contact-resistance.

Tested applications include the following:

Joining dural tubing — *Test samples showed average strength of 3,000 psi.*
Assembly of dural chassis for electrical units—*Flat panels satisfactorily joined.*
Hot-air duct assembly—*Initial tests on 0.064-inch and 0.020-inch dural satisfactory.*
Replacement for metal-to-metal adhesives—*Indicated success, but not yet thoroughly investigated.*
Airfoil smoothing — *Scratched and gouged aluminum surfaces satisfactorily filled.*
Anodized dural surfaces—*Heavily anodized and dyed dural surfaces were tinned directly.*

Other applications will no doubt be disclosed by continuing experimental tests.

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Rocket-Engine Tester

Photoelectric unit utilizing Polaroid discs to generate sine wave checks speed of fuel pumps operating at 40,000 rpm and measures torque required to overcome drag

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ROCKET-POWERED ENGINES of one particular type employ two kinds of fuel. To feed these two propellants to the engine a turbo-driven pump having an impeller at each end is used.

A seal is required at each end of the pump-turbine shaft, which is driven at speeds up to 40,000 rpm. In order to determine the life of the seals during development it was necessary to measure both speed and torque. This had to be accomplished without adding external torque, and the following description explains how it was done electronically.

Principle of Operation

As shown in the diagram, a rotating Polaroid disc and a stationary Polaroid disc, in combination with a system of light sources, lenses, and phototubes, comprise the sine-wave generator of the test device.

The rotating Polaroid disc is mounted on the pump driveshaft. Directly in front of it two light sources and lenses are mounted on a stationary bracket. In back of the rotating Polaroid disc are the stationary Polaroid disc and two phototubes. These are spaced 90 degrees apart to produce similar electrical phase-shift.

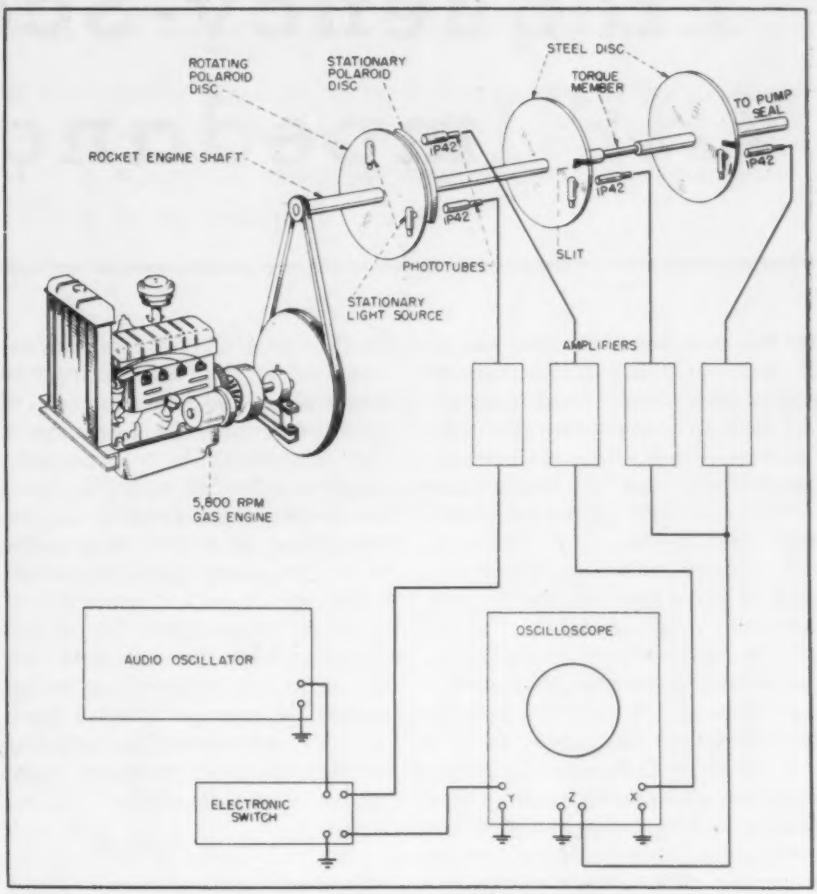
The output of the phototubes is fed to two voltage amplifiers. One of these amplifiers is connected to the X axis of an oscilloscope. The output of the other amplifier is connected to the input of an electronic switch, and the output of the electronic switch is connected to the Y axis of the oscilloscope. To the other input of the electronic switch an audio oscillator is connected.

A circle of 4-inch diameter is produced on the oscilloscope screen when the audio oscillator is tuned to the frequency of the Polaroid generator. The frequency of the audio oscillator multiplied by thirty gives the revolutions per minute of the shaft when the Polaroid generator provides two cycles per revolution.

Also mounted on the pump driving shaft is an opaque disc with a slit 0.008 inch wide and $\frac{3}{8}$" long, cut on the outer periphery. A light source, lens and phototube system much the same as that used in the Polaroid sine-wave generator is employed. Phototube output is fed through voltage amplifier to the Z axis of the oscilloscope. A dark spot appears on the circle developed by the Polaroid generator. An identical arrangement is used on the torque end of the shaft. This produces another spot on the circle, superimposed directly upon the first spot.

Method of Measurement

The spot remains true as long as no load is applied on the torque side of the pump. However, when loads are applied this produces an angular displacement of the torque member, which moves the superimposed spot an equivalent angle. The angular displacement is measured between the stationary spot and the moved spot, by placing a polar-coordinate chart in front of the oscilloscope tube.



Block diagram of the rocket-engine pump-seal tester

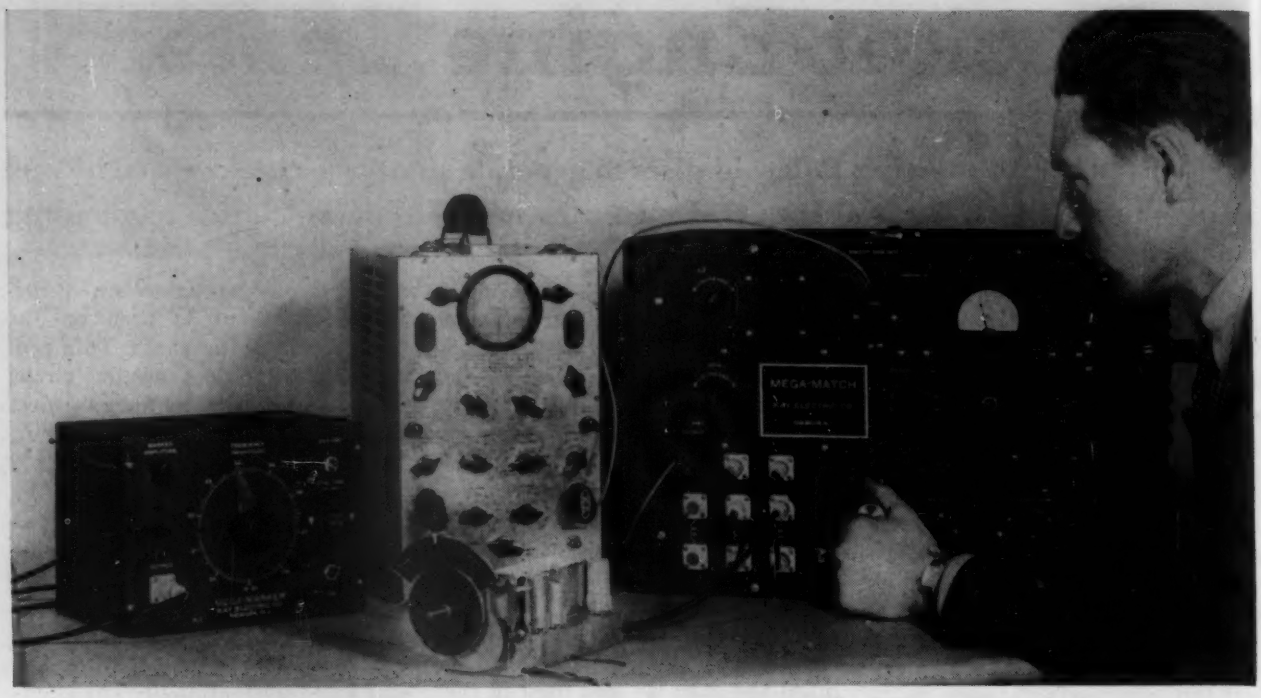


FIG. 1—Frequency-scanning vhf impedance meter in use, with conventional oscilloscope used as indicator

Frequency-Scanning VHF Impedance Meter

IMPEDANCE MEASUREMENTS can be made at radio frequencies by several methods and techniques, using such instruments as the radio frequency bridge, the slotted line, the Q meter and the combination of a calibrated signal-generator with standardized r-f ammeter, voltmeter or reference impedance. Each of these methods has its own particular type of utility. However, in determining the impedance-versus-frequency curve of a particular device, all require tedious point-by-point measurements.

A new instrument has been developed which provides an instantaneous and visually-presented determination of impedance versus frequency. The design of the instrument is such as to enable it to handle almost all of the devices encountered by the radio engineer in the design and development of present-day vhf and h-f equipment. The instrument is a frequency-scanning reflection meter designed for operation anywhere in the range from 10 to 250 megacycles. At any frequency within this range it will rapidly scan a bandwidth of up to 30 megacycles. Its output signal, suitable for use with any oscilloscope, is proportional to the amount of energy reflected from the end of a transmission delay line to which the device or system under test has been connected.

Principle of Operation

The instrument, shown in Fig. 1 and 2, embodies a principle originally used in the terrain clearance meter.[1] It consists essentially of a wide-range sweeping oscillator[2] which is arranged to propagate a frequency-modulated signal through a transmission system of finite propagation time. This propagation time is such that at any instant the reflected energy received back from the far end of the system will be of a measurably different frequency from that being fed into its input.

The pitch of the beat note produced by combining the incident and reflected waves in an internally-contained detector circuit is proportional to the rate at which the frequency is being varied and to the propagation time of the transmission system. The amplitude of

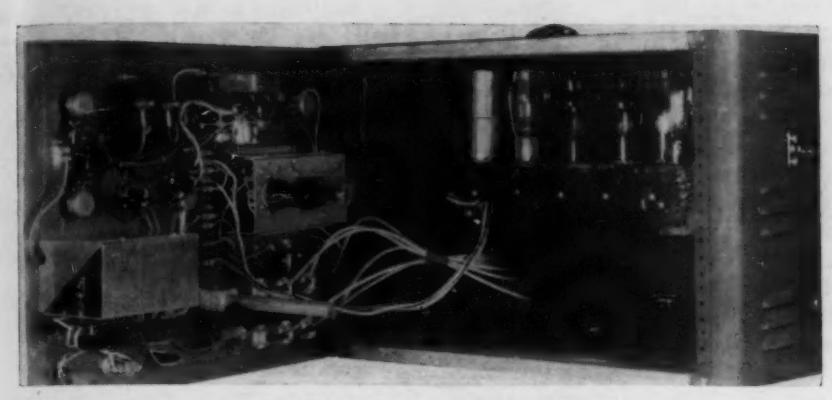


FIG. 2—Inside view of the instrument

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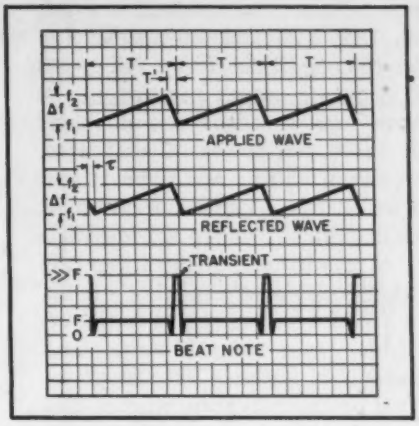

FIG. 3—Frequency vs time relationships existing at the beat-note detector

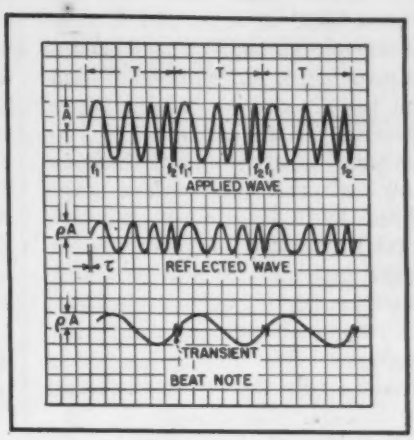

FIG. 4—Amplitude vs time relationships existing at the beat-note detector

Instrument using principle similar to that employed in aircraft f-m terrain-clearance indicators scans bandwidths up to 30 mc in the range between 10 and 250 mc. Details of design are given and the method of operation is described, using termination of an r-f transmission line as an example

the beat note is proportional to the amplitude of the reflected wave.

With reference to Fig. 3 and 4, the conditions which prevail are as follows:

(1) An r-f voltage of amplitude A is linearly frequency-modulated between the limits f_1 and f_2 by a sawtooth waveform of period T.

(2) This voltage is applied to a transmission line whose terminating impedance Z_L does not equal its characteristic impedance Z_o.

(3) The reflected energy due to this inequality is received back at the input after a delay time τ equal to twice the propagation time along the transmission line.

When attenuation in the transmission line is assumed to be negligible and ρ is taken as the transmission-line reflection factor equal to $(Z_L - Z_o)/(Z_L + Z_o)$ the voltage amplitude of the reflected wave will be ρ times the amplitude of the applied wave. The total frequency excursion Δf of the reflected wave will be the same as that of the applied wave. The frequency of the beat note is given by

$$F = \frac{\tau}{T}(f_2 - f_1) = \frac{\tau}{T}\Delta f \qquad (1)$$

The beat note exists for a length of time equal to $T - T'$, where T' is the time of the return sweep. At the end of this time, for the brief interval T', a transient frequency is set up as the applied wave snaps back from f_2 to f_1 to repeat the sweeping sequence.

To a first order of magnitude, it is necessary that the beat-note frequency be such that at least one full cycle of the beat note is completed during the time interval T. As is apparent from Fig. 4, this condition must be fulfilled if a closely sinusoidal beat-note waveform is to be obtained. Therefore

$$T \geqq 1/F \qquad (2)$$

For the case where $T = 1/F$, substituting for T in Eq. 1 gives

$$\Delta f = 1/\tau \qquad (3)$$

In order, therefore, to secure at least one full cycle of beat note, the total frequency deviation must equal the inverse of the total propagation time outward and back through the transmission line. The amount of frequency excursion during one cycle of beat note will determine the frequency resolution

of a particular reflection measurement.

Description of Instrument

In the instrument, a band-pass audio amplifier with variable gain is used in conjunction with the beat-note detector. This combination results in high sensitivity of measurement of reflected energy. In order to reach the best compromise between high gain, good stability and low susceptibility to disturbance from unwanted signals, the amplifier is designed with a pass band of from 300 to 6,000 cycles per second. The beat-note detector is a silicon-crystal diode and the frequency-sweeping signal generator is an oscillator[2] plus an auxiliary 2,000-cps sawtooth modulator of the phantastron type. Three fixed lengths of RG-58/U coaxial transmission line are included internally to provide a suitable transmission delay for most of the applications generally encountered. The propagation velocity along this type of line is about 660 feet per microsecond.

The diagram of Fig. 5 shows the essential elements of the frequency-scanning reflection meter. The portion within the dotted line is the oscillator with its normal 60-cps sawtooth frequency modulation applied to the high-level (local) oscillator. The frequency excursion can be adjusted to as high as 30 megacycles or more. The adjustable output of the 2,000-cps sawtooth modulator is applied to the low-level (signal) oscillator, permitting sweep excursions of up to 5 megacycles. The 60-cps sweep rate is intended for very-high-frequency (30 to 250 megacycles) broadband work, whereas the 2,000 cps sweep rate is designed for high-frequency (10 to 50 megacycles) medium and narrow-band work.

With the various combinations of transmission line lengths included in the instrument, total delay times of 0.2, 0.4, 0.6, 0.8 and 1.0 microseconds are available. From Eq. 3 the respective sweep widths for obtaining one complete cycle of beat note output are 5.0, 2.5, 1.67, 1.25 and 1.0 megacycles. For the condition of two full cycles of beat-note output per sweep, the above sweep widths are doubled; for three full cycles of beat note, the sweep widths are tripled; and so on. This permits operation of the instrument under a wide variety of conditions, using either the high-frequency sweep rate or the low-frequency sweep rate as the individual case may dictate, and patching in suitable lengths of internal or external transmission line as required.

Applications

One typical use of the instrument is described in the following paragraphs.

Suppose it is necessary to evaluate the impedance of a coaxial-sleeve broad-band vertical dipole antenna designed for operation in the 50 to 60 megacycle region from 53.5-ohm coaxial transmission line. The antenna is mounted on an elevated support about 80 feet from the point at which the test instrument is most conveniently located, and an attached 100-foot length of 53.5-ohm coaxial cable is brought down to the test location. It is desired to observe visually the reflected energy from this antenna over the frequency range of 40 to 70 megacycles, and this information is desired with a frequency resolution of about 2 megacycles.

The ratio of total sweep width to desired frequency resolution is $30/2 = 15$, so that 15 full cycles of beat-note output per sweep are required. Hence, modifying Eq. 3 for this case.

$$\Delta f = 15\,(1/\tau) \qquad (4)$$

so that

$$\tau = 15/30 = 0.5 \text{ microsecond} \qquad (5)$$

The same figure may be arrived at by noting that the 2-megacycle resolution requirement is equivalent to saying that the applied frequency must shift at the rate of 2 megacycles per beat-note cycle. It then follows directly from Eq. 3 that $\tau = \frac{1}{2}$ microsecond.

A two-way delay of 0.5 microsecond requires a one-way length of solid-dielectric coaxial cable of 166 feet. Since the 100-foot feeder cable is already available externally, it is only necessary to add a single 66-foot length of internal cable from that available in the instrument to make up the necessary transmission system. The setup is as follows:

A patching cable is connected between connectors P_1 and P_2. Another patching cable is connected between P_3 and P_4. The feed cable from the antenna is connected to P_5. The sweeping output is set up for a center frequency of 55 megacycles, with the 60-cps sawtooth generator set for 30 megacycles of total sweep width (the 2,000-cps sweep is set to zero for this particular application). The 60-cps sawtooth-sweep output terminals are connected to the horizontal sweep input of any commercial oscilloscope, and the output of the band-pass audio amplifier is connected to the vertical input of the oscilloscope.

The visual pattern of the desired data will resemble the sketch of Fig. 6. The 15 complete beat-note cycles, swept every 1/60 of a second (F = 900 cps), are modulated by

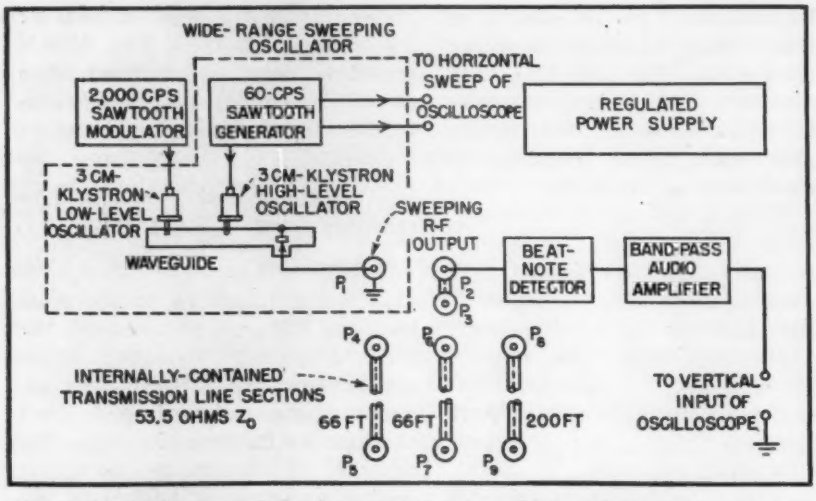

FIG. 5—Block diagram of the frequency-scanning vhf impedance meter showing lengths of transmission line available within the instrument

an envelope whose amplitude represents the amount of reflected energy as a function of instantaneous frequency. As can be seen, the reflected energy approaches zero in the region of 55 megacycles, at which point the antenna impedance closely matches the characteristic impedance of the transmission line. At either extreme of the frequency excursion the reflected energy approaches that which would be obtained if the transmission line were terminated in an open circuit. It is thus possible to tell at a glance just how effectively a given antenna matches its transmission line, and over how wide a frequency band it does so.

Transmission-Line Attenuation

Since attenuation is present to some extent in all practical transmission systems, the amplitude of the reflected voltage wave as received back at the beat-note detector is not strictly equal to ρ times the voltage amplitude of the applied wave, but is $\eta^2\rho$ times this amplitude, where η is the voltage attenuation ratio suffered by the wave in traversing the length of the line one way. However, it remains true that the amplitude of the reflected wave received back at the beat note detector is proportional to the magnitude of the reflection factor. For an open-circuited or short-circuited termination of the transmission line the magnitude of ρ is always unity. For an arbitrary terminating impedance it is possible to evaluate the magnitude of the reflection factor, and hence the magnitude of the terminating impedance, by the following procedure:

First, the transmission line to be used is terminated in a short-circuit, corresponding to a reflection factor of amplitude unity, and the amplitude of the resultant beat note is adjusted to any convenient reference value, such as two inches peak-to-peak. Then the arbitrary terminating impedance is connected across the transmission line in place of the short-circuit and the peak-to-peak height of the resultant beat-note wave displayed on the oscilloscope screen is measured. The ratio of the height at any particular frequency to the two-inch reference height is then the magnitude of the reflection factor at that frequency. The phase angle of the reflection factor may be obtained by comparing the phase of the beat-note wave at any particular frequency to the phase of the two-inch reference wave. With this information, the terminating impedance may then be calculated with the aid of the Smith Chart.

From the above description it is apparent that a knowledge of the transmission-line attenuation is not essential to the operation of the instrument. However, excessive transmission line attenuation is to be avoided since there is a practical limit even in the most carefully manufactured delay cable or transmission line to the uniformity of characteristic impedance with length. The minute irregularities in Z_0 which exist cause small reflections to occur early in the line which may completely mask the reflection due to the terminating impedance when the cable attenuation per unit length is high and the line length large. It is fortunate that for vhf applications, where the transmission line attenuation is rather high, it is generally satisfactory to work with frequency resolutions of the order of about three megacycles.

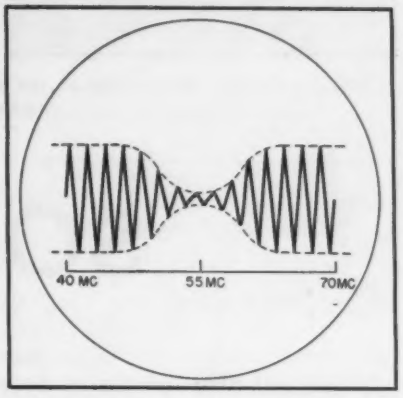

FIG. 6—Typical visual presentation of reflected energy on an oscilloscope screen

Transmission-line lengths of the order of 100 feet may then be employed without excessive total attenuation. For frequencies below the vhf range the transmission-line attenuation is conveniently low, so that longer lengths may be used to achieve the finer absolute frequency resolution which is usually desired here. A relative frequency resolution of from 2 percent to 5 percent of the center frequency is satisfactory in most cases. The sum of the lengths of cable contained within the instrument provides a minimum absolute frequency resolution of about one megacycle. For narrower resolutions than this, the addition of a suitable length of external transmission line is required. Similarly, if resolutions of less than about 2 megacycles are desired in the upper portion of the vhf band it will probably be necessary to use a suitable length of lower-loss transmission line than that contained within the instrument.

Operation With Balanced Circuits

For measurement of balanced impedances two methods have proved satisfactory. The first method involves the use of coaxial transmission line in conjunction with a suitable balanced-to-unbalanced transformer to connect the impedance to be measured to the line. The second method makes use of an external length of balanced transmission line of the twin-lead type developed for use with present-day television and f-m receivers. This transmission line may be set up in the laboratory by stringing a suitable length back and forth between pegs located on the walls in such positions that the sections of line thus formed are spaced two or three feet from each other. The balanced impedance to be measured may then be connected to one end of this line, while the other end of the line is connected to the coaxial output connector of the instrument.

Tests have shown that this type of balanced transmission line arrangement then acts as its own balanced-to-unbalanced conversion system to a satisfactory degree. Futhermore, tests have also shown that transmission-line impedances of from 50 to 300 ohms may be used without encountering trouble from second-time reflected waves.

References

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(2) Wide Range Sweeping Oscillator, Kay Electric Co. Eng. Staff, ELECTRONICS, p 112, August 1947.

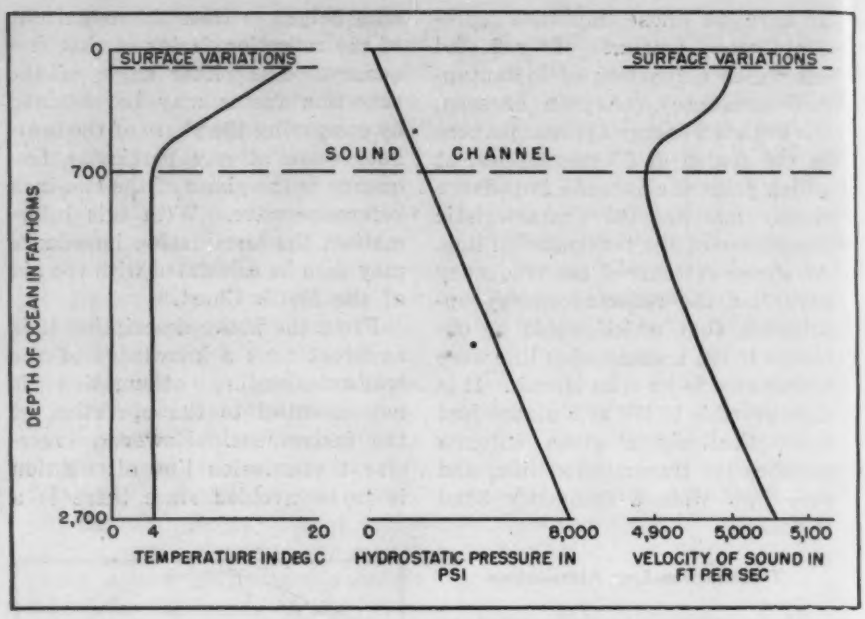

FIG. 1—Graphic explanation of the sound channel effect upon which the sofar system depends

SOFAR

A hyperbolic position-determining system that depends upon propagation of sound from a bomb exploded at a 4,000-foot depth in the ocean. Accuracy of fixes is within five miles at 2,000-mile range. Continuous monitoring equipment used to time arrival of impulse is described

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SOFAR, from the initial letters of the words SOund Fixing And Ranging, is the code name of a position-determining system. The sound transmissions on which it depends have been heard all the way from Dakar to the Bahamas. The system was designed specifically as a rescue measure in locating castaways at sea or survivors from a ditched plane.

In operation, the castaway drops a bomb weighing 1 to 4 pounds into the water. The bomb has been set to explode at a depth of about three-quarters of a mile. Observers at each of three or more continuously operating receiving stations time the instant of arrival of the peak sound pressure to the nearest tenth of a second. The bomb is then located on one of a family of hyperbolas confocal to a pair of receiving stations. Any two of the three observation points constitutes a pair and the fix, or actual location in terms of latitude and longitude, is the point at which two lines of position cross. The lines of position are generated by the differences in time of arrival of the underwater signal.

The geometry is comparable to that of navigational systems like loran except that the transmitting and receiving stations are interchanged. Accuracy of a fix is within five miles at a range of 2,000 miles.

Sound Channel Effect

The sofar system is based on a phenomenon in the field of sound physics which was verified experimentally during the war. This phenomenon, which has been called the sound channel effect, is the result of refraction of sound waves by layers of water. Practically speaking, because of these refraction effects, there is a horizontal channel deep down in the ocean through which the sound of an explosion can travel for thousands of miles.

Sound waves, like light waves, are bent as they travel through media in which the velocity of propagation varies. Such refraction, caused by velocity changes in the water, is accountable for the sound channel effect.

In the open sea, the velocity of sound is dependent primarily on temperature and pressure. The velocity decreases with decreasing temperature and increases very slightly with increasing pressure. Generally speaking, temperature decreases with depth. At the same time, the hydrostatic pressure increases. The two effects, therefore, work in opposition. This effect can be seen graphically in Fig. 1, which was prepared from studies of the North Atlantic Ocean by the Woods Hole Oceanographic Institution.

At depths of less than about 4,000 feet (this critical depth varies from ocean to ocean), the variation in temperature is relatively more important than the change due to pressure variation. Below this depth, there is practically no change in temperature, but because of increasing pressure the velocity increases. The 4,000-ft level, therefore, becomes a stratum

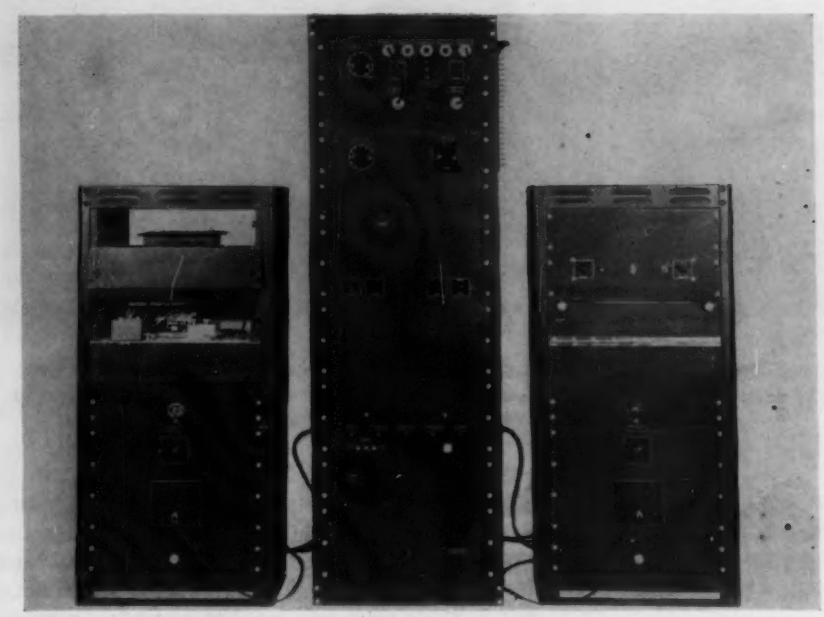


FIG. 2—Experimental sofar receiving station. Recorders and timing equipments are in smaller racks. Center cabinet contains controls, amplifiers and power

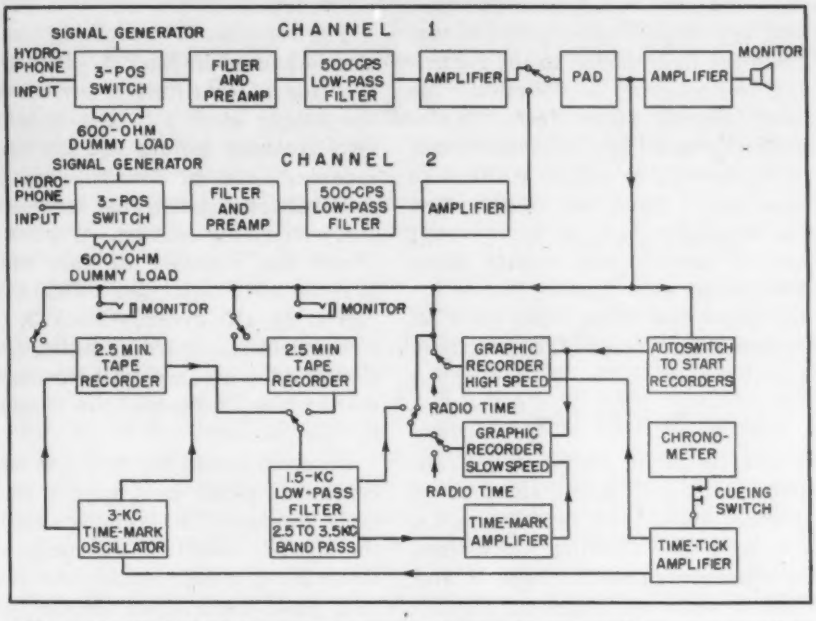


FIG. 3—Simplied block diagram of more important elements making up a complete monitoring station

of minimum sound velocity. Sounds originating at this depth are refracted downward from above and upward from below. As a consequence, sounds are horizontally channeled.

Sounds originating at a depth of 4,000 ft spread horizontally within the sound channel in much the same way in which sounds in air go echoing down a canyon. This phenomenon has a number of rather interesting effects on the characteristic of the sound wave as it is received at some great distance from the source. For example, a sound ray leaving the source at an inclination to the horizontal has a tendency to cross and recross the horizontal layer indefinitely until it is finally attenuated below the ambient noise level.

As a consequence, sound may theoretically travel by an infinite number of different paths between the source and the receiving pickup —particularly if the separation between sound source and pickup is very great, for example, of the order of several hundred miles. Furthermore, the most direct route, that is, the horizontal path from source to pickup, is also the slowest; because those ray paths inclined from the horizontal lead into strata of higher sound velocity which then bend back some of the rays and produce the phenomenon described above as a crossing and recrossing of the axis of the sound channel.

Multipath Effect

It was found rather early in the series of experiments to determine the nature of sound channel transmission that sounds arriving at the receiving element commence at a low intensity, gradually building up to a loud crescendo with a very sharp cutoff—an effect which has been described as the kettledrum. The cutoff occurs, it is believed, when the sounds which have traveled by the slowest route (and at the same time the route of most nearly constant depth) arrive. The cutoff is so sharp that there is practically no possibility of mistaking it, and the instant at which it occurs can be determined to within 0.1 second. The buildup time of the sound wave received after spreading is about 1.2 seconds per 100 miles. Furthermore, the character of a sound-channel explosion is so distinct that it cannot be confused with stray explosions at other depths.

Design Considerations

Experimental work demonstrated that the primary specifications for sofar monitoring equipment should include:

(1) sensitive response from 30 to 300 cycles;

(2) self-noise of the amplifiers at an absolute minimum;

(3) provision for switching quickly from one hydrophone to another, with, at the same time, some means for introducing a signal generator for equipment calibration and maintenance;

(4) suitable means for indexing actual arrival time of the signal

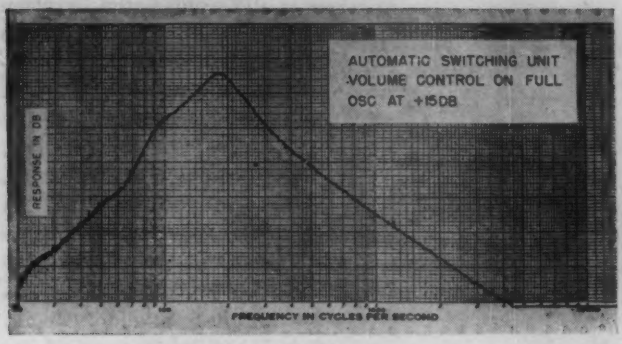


FIG. 4—Response of the automatic switching unit that turns on recorders when bomb signal starts arriving. The device triggers at 175 cycles

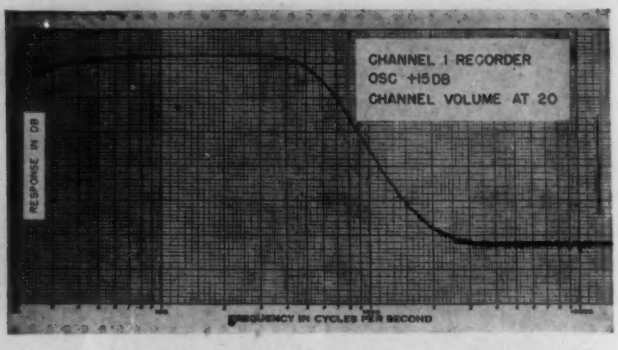


FIG. 5—Response of an amplifier channel incorporating a 500-cycle low-pass filter. Overall noise is 27 db below that of typical amplifier

(to 0.1 second) and means for obtaining chronometer correction by introducing WWV time signals.

In order to expedite delivery of the intial group of monitoring station equipment, it was decided to utilize readily available commercial equipment modified as required, supplementing this with those units which required special design or treatment. Figure 2 is a front view of the three racks which house all the apparatus for each station except the bass reflex speaker used for aural monitoring. This equipment provides integrated receiving, recording and timing units for each network station. The equipment is built to operate continuously, day after day, although the incident that it is designed to note and report to the operator takes only a few seconds and may not occur for months at a time.

Figure 3 is a block diagram of the receiving station. Several hydrophones located in the sound channel are connected by submarine cable (sometimes 12 to 15 miles long) to the hydrophone input receptacles at the top of Rack 1, center of Fig. 2. One hydrophone is patched into the operating amplifier channel.

The hydrophone amplifier circuits terminate in a system bus, contained in a unit identified as the Chronometer Time Control and Phone Monitor. The functions of this unit are: to act as a distribution center for the amplified signal from the hydrophone to the recording components; to distribute the time indexing pulses from the circuits controlled by the break-circuit chronometer; to separate the 3-kc tone pulses from the signal when the magnetic tape is reproduced; and to amplify and rectify these 3-kc pulses as a driving source for the paper tape time index relay on reproduction from the magnetic tape.

Recording Data

The recording units, which consist of a dual installation of a graphic sound level recorder and a magnetic tape recorder, are housed in separate cabinets, Rack 2 and Rack 3 (left and right in Fig. 2) cable-connected to the main rack. A time indexing and auto-start, as well as selective input control and monitoring position were added to the basic graphic recorder. In the magnetic tape recorders the speed was made adjustable from one minute normal to a maximum duration of 2.5 minutes without sacrificing the frequency response below 500 cycles.

The automatic switching unit also is housed in Rack 2. It is the function of this unit to switch on the supply circuit to the graphic level recorder motors and the time indexing control relay when a sound channel shot signal arrives at the monitoring station. Figure 4 shows the response of this unit. It is designed to trigger a 2050 thyratron at 175 cycles. Rack 3, in addition to its recording units, also contains the break-circuit chronometer which initiates the timing circuit pulses.

Figure 5 shows the response of a typical amplifier unit with a 500-cycle low-pass filter incorporated in the circuit. With input energy of the order of a microvolt over a narrow pass band from 30 to 300 cycles, the normal undistorted voltage gain is 107 db. At maximum gain with input terminated in 600

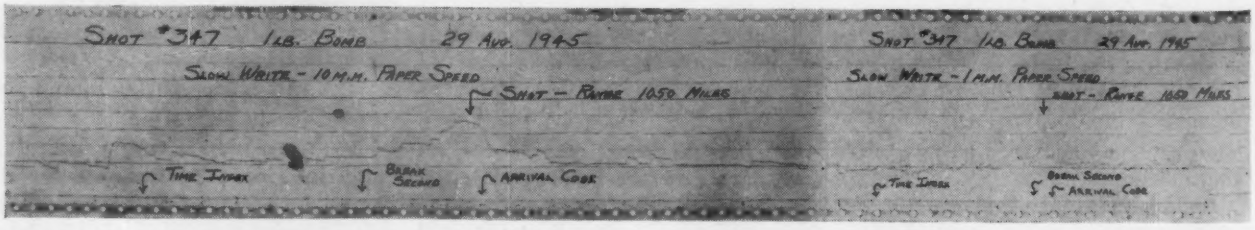

SHOT #347 1 LB. BOMB 29 AUG. 1945
SLOW WRITE - 10 M.M. PAPER SPEED
SHOT - RANGE 1050 MILES
TIME INDEX
BREAK SECOND
ARRIVAL CODE
SHOT #347 1 LB. BOMB 29 AUG. 1945
SLOW WRITE - 1 M.M. PAPER SPEED
SHOT - RANGE 1050 MILES
TIME INDEX
BREAK SECOND
ARRIVAL CODE

FIG. 6—Slow and fast graphic recordings of bomb signals from 1,050 miles. This record has been made from a replaying of the magnetic tape record. Point of maximum energy is timed to an accuracy of 0.1 second. The arrival code mark is made by the observing operator when he hears the maximum signal arrive and is chiefly useful in identifying the peak

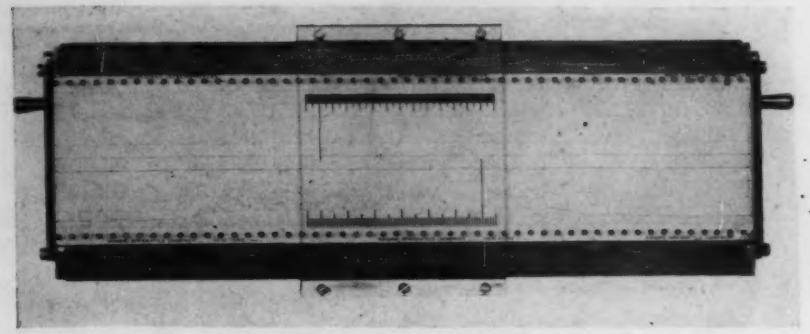


FIG. 7—Shot arrival time evaluator for two different recorder speeds. The long vertical line is placed over the maximum signal and tenths of seconds read off to the nearest chronometer time mark

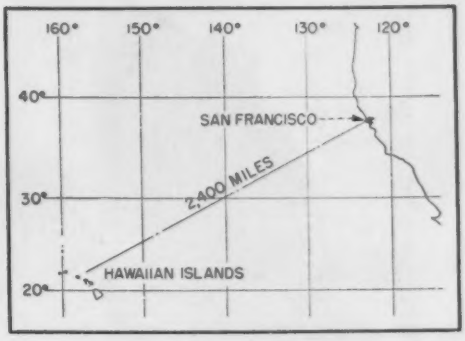


FIG. 8—Pacific Ocean Air-Sea Rescue network showing experimental stations in California and the Hawaiian Islands

ohms the overall self-noise of a typical amplifier channel as measured on a vtvm (terminated in 600 ohms) is 27 db below 1 volt.

In normal operation the equipment listens continuously. One of the magnetic tape recorder units continuously records the sounds picked up by the hydrophone and erases automatically two and a half minutes later.

With the arrival of energy from a sofar bomb, the visual recording equipment is triggered by the buildup of the amplitude of the received signal, and the station operator is alerted by means of a suitable warning device. Inasmuch as the signal comes in rather slowly, building up to a crescendo before the cutoff, the gating circuit is actuated with ample time for the operator to process the shot reception. First he must press the cue switch which breaks the chronometer control circuit, thus providing a secondary timing mark on the visual tape as well as a 3-kc tone pulse on the magnetic tape recorder. This cue mark, labeled "arrival code" in Fig. 6, enables ready identification of the time to the nearest minute and second.

The operator switches the operating magnetic tape recorder to an inoperative condition. He then turns on the stand-by magnetic tape recorder to record and switches it to the system bus. After restoring the automatic switching unit to stand-by the listening operation of the station continues, and the operator is free to observe the arrival time of the signal just received and recorded. Since this signal has also been recorded on the magnetic tape recorder, the operator can play back this recording and reproduce it on the stand-by graphic level recorder in order to obtain another trace of the received signal.

Normal visual tape speed is 5 mm per second. However, on playback from the magnetic recorder, the operator can adjust the paper tape speed of the recorder to 10 mm per sec to increase the resolving power by a factor of two.

Timing Circuit

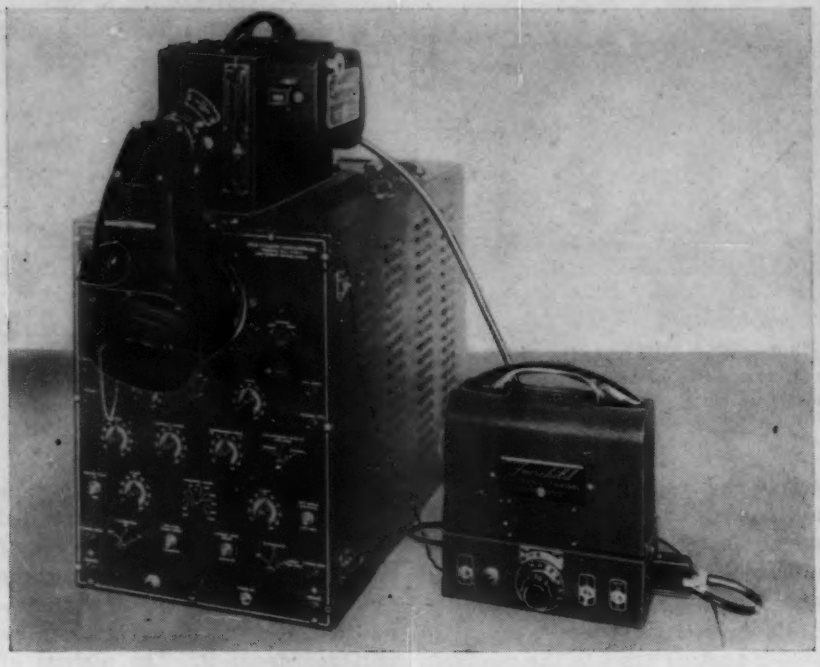
A standard Navy break-circuit chronometer is connected to each of the d-c amplifiers which actuate recorder paper indexing styli. This chronometer breaks the circuit once each second, except the 59th in every minute. The break-second mark appears clearly on the transcriptions shown in Fig. 6. One of the two amplifiers keys a 3-kc oscillator which feeds a signal into the magnetic tape recorders, allowing 3-kc pulses to be recorded on the tape in synchronism with the chronometer.

When the magnetic tape recording is played back to the sound level recorder, the 3-kc pulses are separated from the signal by a band-pass filter, are rectified and are switched to the sound level recorder paper indexing stylus. By the use of the code mark, the sound level recorder paper for a particular shot as originally recorded can be lined up with the sound level recorder paper of this same shot as recorded from the magnetic tape recorder. In this way is afforded an alternate graphic level record of the complete signal, showing the dynamic range. An accurate measure of the time of arrival can be obtained from it. The picture of the shot arrival time evaluator, Fig. 7, shows a typical trace lined up for measurement.

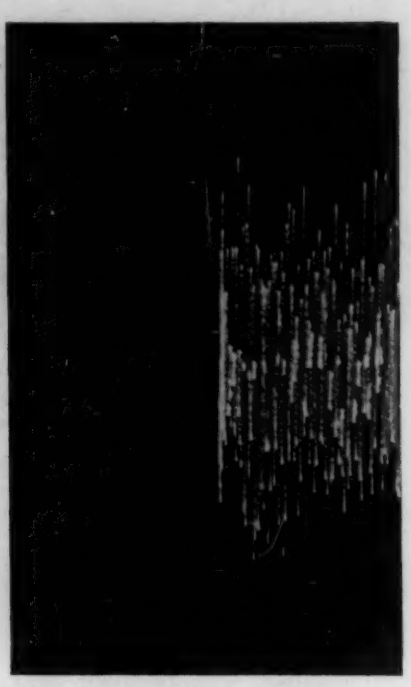
Plans are now well under way for the installation of the first permanent three-station network. The primary responsibility for completing the installation of this network, carrying out the operational tests, and conducting additional sofar research, is being prosecuted by the U. S. Navy Electronics Laboratory in San Diego. One station has been established in Hawaii and tested satisfactorily by means of bombs dropped off the California coast, 2,000 miles distant. The other two will be on the west coast, located in positions suitable for covering the California-Hawaii air routes.

Acknowledgement

Credit for experimental verification of the sound channel effect belongs tc the Woods Hole Oceanographic Institution, at Woods Hole, Massachusetts, where Dr. Maurice Ewing was the principal scientist involved in the cooperative enterprise with the U. S. Navy Underwater Sound Laboratory. Among the many who contributed much to this task are J. L. Worzel, J. E. Peoples, R. J. McCurdy, W. S. Latham, W. B. Watkins, and R. E. Maxwell.



Camera mounted on oscilliscope, and electronic film-speed control unit



Example of film acceleration

An Oscilloscope Camera

Continuous recordings of oscilloscope patterns are made on film or paper at speeds from one inch per minute to five feet per second, a range of 3,600 to 1, using electronic motor control. Either film motion or the oscilloscope sweep can be employed as the time base

Most oscilloscope pictures are made with cameras designed for general photographic purposes and not particularly suited for recording oscilloscope patterns.

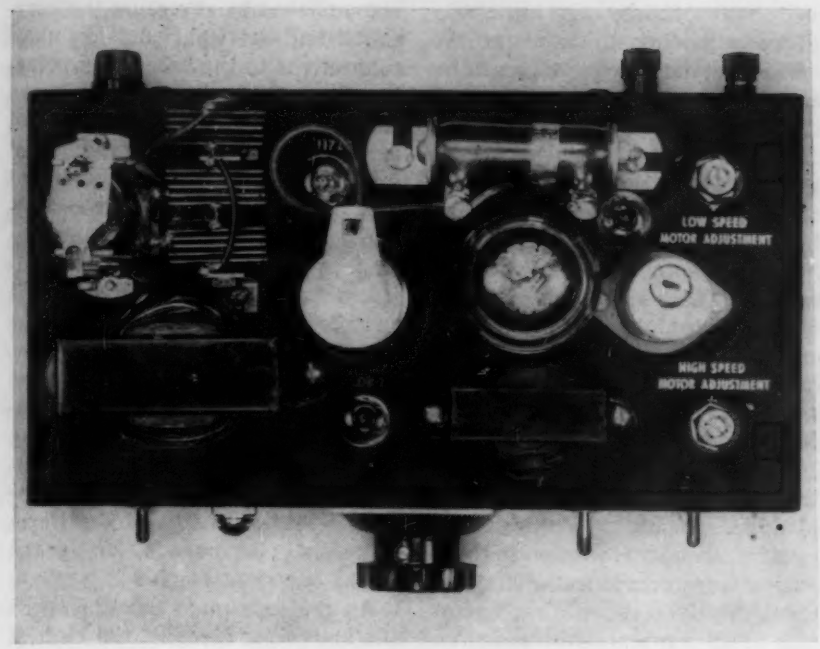
The camera to be described is designed for both still and continuously moving film photography. For still photography of stationary patterns, single transients or data records, a shutter with speeds of 1 second to 1/400 second, plus time and bulb, is provided. This shutter must be kept open when making continuous recordings, so an interlock is provided to prevent any possibility of running the film through with the shutter closed or inadvertently leaving it open while taking a series of still pictures.

For continuous recordings, a speed range of 3,600 to 1, from 1 inch per minute to 5 feet per second, is provided by means of a specially designed electronic control and a two-speed clutch. The electronic control provides smooth, uniform speed continuously variable by means of a single-dial control from 1 inch per minute to 60 inches per minute, or 1 inch per second to 60 inches per second, depending upon the position of the clutch.

The clutch is shifted by a simple push-pull knob which inserts or removes a 60-to-1 gear ratio. It may be operated while the camera is running, so that it is possible to set up for a recording on low speed and shift to high at the desired instant, giving extremely fast acceleration of less than 0.01 second to reach maximum speed.

Many types of mechanical drives were tried in the development of this camera, including change gears, cone pulleys and variable cone, but it was found that the electronic control not only gave better performance but was cheaper to produce. Furthermore, the electronic control gave a continuously variable speed control which maintains any set speed without fluctuation due to variations in load and line surges. Such precise control is absolutely essential to be sure that any variation in the recorded pattern is due to actual changes in the oscilloscope pattern and not due to fluctuations in film speed.

To give an accurate record of the exact rate of film movement, a small neon lamp is mounted so it will record along the edge of the film when fed suitable voltage.



Top view of motor speed-control chassis

By H. E. HALE and **H. P. MANSBERG**

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When taking still pictures, the film is advanced manually by means of a lever provided with an adjustable stop which permits advance of ¼ to double a standard 35-mm frame height (5 to 39-mm). However, if it is desired to take a large number of stills in succession the continuous film drive can be used by adjusting it to a speed which will separate successive pictures by the desired amount and by blanking out the screen with Z-axis modulation except during the interval when recording is desired. The blanking signal can be removed by the transient to be recorded, or by a relay or snap-action switch.

The camera is mounted on top of the oscilloscope with a reflecting mirror system in a light-tight housing to bring the scope image up to it. This periscope type of mounting gets the camera out of the operator's way, and provision for simultaneous viewing and recording is easily provided by a port over the lower mirror.

A filter excludes most extraneous light which would affect the film when the port is open for viewing, and a guillotine shutter closes the port entirely at other times. A rubber ring at the lower end of the periscope fits up against the cathode-ray tube to exclude all light and at the same time locates the mount accurately so that no focusing is required. The camera is prefocused at the factory.

Data Record

An illuminated data card mounts on the front of the periscope by means of spring clips, when not in use. Handwritten data may be put on the finely ground Lucite surface with an ordinary pencil and removed with a pencil eraser.

The camera uses standard 35-mm film or paper, and has an internal capacity of 100 feet, with provision for mounting a 1,000-foot magazine externally. With the 100-foot reels, the camera will operate from 20 seconds at the maximum speed to 20 hours at the minimum speed; with a 1,000-foot magazine it will operate from 3⅓ minutes to 8⅓ days, respectively.

A footage indicator shows the number of feet exposed regardless of whether 100-foot reels or 1,000-foot magazines are used, or whether the film is advanced manually or by the motor. The camera may be loaded or film removed in daylight.

A coated f/2.8 lens is supplied as standard equipment but an f/1.5 lens is optional. With the f/2.8 lens and accelerating potentials of 3,000 volts on a type 5CP11A cathode-ray tube, writing rates up to 0.8 inch per microsecond can be recorded. With a type 5RP11A tube and 29,000 volts accelerating potential, rates up to 70 inches per microsecond can be recorded. The corresponding writing rates with the f/1.5 lens are 3 and 270 inches per microsecond respectively.

Electronic Control

The circuit used in the electronic speed control of the Oscillo-Record Camera is shown in Fig. 1. A type C1B thyratron supplies the armature voltage to the motor. The control voltage is obtained from a 117Z3 rectifier with an OB2 voltage regulator used to eliminate line-voltage fluctuation effects. Bias voltage is obtained from a selenium rectifier and two other selenium rectifiers supply the motor field. A second OB2 maintains constant bias voltage. Current in the field of the motor is maintained constant with a current-regulating tube. The 117Z3 also supplies a time-delay relay which prevents application of power to the thyratron until it has had sufficient time to warm up.

In addition to the d-c applied to the grid of the thyratron to control the speed of the motor, a small amount of a-c is superimposed on it. With the d-c alone, the smallest portion of a cycle during which the thyratron can fire, if it fires at all, is ¼ cycle, with a maximum of ½ cycle.

By superimposing a small amount of a-c properly phased it is possible to cause the firing to occur much later in the cycle so that current is passed during only a very

Data record photographed from pencilled note on illuminated card

small fraction of a cycle when the power requirements are low. In this way, in place of the motor receiving a large slug of power followed by several cycles with no power, a small amount of power is supplied to it each cycle. This practically eliminates speed fluctuations which would otherwise cause uneven film speed. It also provides excellent speed control over a much wider range of speed and load conditions than would otherwise be possible.

Methods of Recording

The fundamental recording techniques possible with the camera are: single-frame exposure on stationary film, continuous-motion photography employing the film motion as a time base (which we shall refer to as the first method), and continuous-motion photography employing the oscilloscope sweep as a time base, transversal to the motion of the film (which we shall refer to as the second method).

A paper written in 1944 thoroughly discusses the various factors generally involved in oscilloscope photography.[1] In this paper, the relationships between the luminescent-spot writing rate, the lens aperture and optical-magnification ratio were derived and methods of calculating exposure were given. A Du Mont camera specifically designed for single-frame exposure photography only has recently been placed on the market. The Oscillo-Record Camera also has provision for this type of recording in addition to its primary use as a continuously moving film camera.

This method of recording can be used for the photography of either highly repetitive phenomena or single-transient phenomena where the duration of the transient is not longer than the longest sweep of the oscilloscope used, unless one wishes to photograph only individual parts of the long transient.

In photographing repetitive phenomena, the camera shutter speed should be set so that it opens for at least the duration, and preferably longer, than the time of one complete cycle of the oscilloscope sweep. The exposure, of course, should be sufficient to obtain useful negative density for the highest writing-rate components of the signal.

To photograph single transients, the camera shutter is best set at bulb or time, opened before the transient occurs, and closed after the transient has disappeared. For this purpose, an oscilloscope having a triggered sweep and automatic beam control is preferred. With such an instrument, the screen of the cathode-ray tube is blank before the transient occurs. When the sweep is initiated by the transient, the trace is blanked in for the duration of the sweep, and there is no fogging of the film by a luminescent spot or line before or after the transient.

When very long exposures are to be used with high-speed panchromatic film, fogging of the film may result due to a very weak glow coming from the heater of the cathode-ray tube. The fogging can be prevented by the use of a blue filter in front of the cathode-ray tube screen.

Film Speed Time Base

An example of the method of recording that uses the film travel as a time base is shown at the top in Fig. 2. The two pulses which appear recurrently are seen to have constant spacing, indicating the constant speed of the film. To make such a recording, the signal must appear as a horizontal deflection of the spot on the cathode-ray tube screen since the motion of the film in the Oscillo-Record Camera is vertically upward. This is best accomplished by reversing the horizontal and vertical deflection plate connections to the tube or by rotating the cathode-ray tube clockwise through 90 degrees. By doing this, rather than just feeding the signal into the X amplifier, the signal may be observed before the recording is started, using the oscilloscope sweep. Then, when all adjustments are made, the sweep is switched off and the camera motor is started.

This method of recording is useful where the signal to be photographed occurs too slowly for an observer to study, even on a long-persistence screen, or when the signal consists of a non-uniform recurrent phenomenon, or if the signal occurs at random.

At the maximum camera speed (60 inches per second), the highest frequency which can be recorded is limited by the resolution of the film and the luminescent spot size. With high-speed film emulsions, such as Eastman Kodak Linograph Ortho and Linagraph Pan, the limit frequency for this method of recording is about 10,000 cycles.

For a particular cathode-ray tube screen, the frequency limit due to persistence, for continuous motion recording, is known as the blurring limit. This limit is approximately 200 kilocycles for a P11 screen and is therefore well above the resolution limit at 60 inches per second. When a time reference is desired, a signal voltage of known frequency may be connected to the small neon bulb in the camera; a narrow time-marker track is then recorded at the edge of the film.

The second method of recording, that of recording the oscilloscope sweep across the width of the film, is illustrated by the bottom trace in Fig 2. The pulses shown are the same as at the top and were obtained by differentiating a sawtooth wave. Both oscillograms were made on the same strip of film by running the film through the camera twice; recording once by the first method, with the beam positioned to one side of the cathode-ray tube screen, and then recording by the second method, with the beam positioned to the other side of the screen.

Although the film was run at the same speed in both cases, the distance between pulses at the bottom in Fig. 2 is much greater and, had the signals been more complex, this additional space would have been necessary. As stated previously, it is only necessary to run the film at a rate of speed sufficient to provide some separation of the successive sweeps and the signals imposed thereon. The angle at which the sweep base-line appears is determined by the ratio of the oscilloscope sweep speed and the film travel speed. When the film speed and sweep speed are equal, the base line records at a 45-degree angle, and when the sweep speed is much greater than the film speed, the base line is essentially perpendicular to the film length.

The film speed at which the successive sweeps, and the signals imposed on them, are just separated, can be calculated from the formula

$$S = f_s h/6$$

where S = the necessary film speed, f_s = the sweep frequency, h = the height of the signal peak appearing on the cathode-ray tube screen.

The factor, 1/6, is the optical-reduction-ratio of the camera lens. In many cases where the signals appear immediately below one another the film can be run slower than S, so that one signal appears inside the other or interlaces without overlapping (as in Fig. 9).

When the signal being recorded is a sine wave or any other pattern having negative as well as positive amplitudes, and the peaks of the signals on the successive sweeps do not interlace, then h will have to be taken as the peak to peak amplitude. The highest frequency that may be recorded by this method is limited only by the maximum sweep speed available and the maximum photographic writing rate of the oscillograph. (Maximum photographic writing rate is defined as the maximum writing speed of the luminescent spot on the cathode-ray tube screen, which produces a recording density of 0.1 above film fog at an optical object: image ratio of $M = 1$ with a lens aperture of f/1 and with a high sensitivity film emulsion processed in a high contrast developer.)

Occasionally, certain phenomena are observed which have extremely rapid variations at the beginning and then undergo a slow rate of change with a duration many times longer than the initial transient. To record such phenomena completely, with sufficient detail for analysis, it would be necessary to run the film at extremely high speeds. Besides being uneconomical, this procedure would make it difficult to study the latter part of the signal which, since it has a slow rate of change, would be spread over a great length of film.

It may be possible in a few cases, by watching the pattern through the camera's viewing eyepiece, to switch the film speed from high to low by means of the speed-change clutch but this is usually impractical. The second method of continuous-motion recording might then be used, but the continuity of important parts of the phenomenon may be lost due to the many successive sweeps.

For Transients

In a third method of continuous-motion recording, a single driven-sweep of the oscilloscope is used to rapidly deflect the spot vertically upward at the start of the phenomena, as the film in the camera moves slowly in the same direction. The signal is impressed horizontally on the spot; at the end of the single sweep the spot is not blanked out but remains in position. The effective speed of the time base during the sweep is equal to the vector sum of the optically-reduced sweep speed and the film speed and, after the sweep, is equal to the film speed alone. Sweep and film speeds should be chosen to provide optimum spread of the rapid transient and the slow rate of change part respectively Only one time-base discontinuity then exists at the end of the sweep travel. Even this discontinuity can be avoided by the use of an exponential sweep rather than a linear sweep. That is, the exponential curve of the sweep rate can be made asymptotic to the film speed. Where a number of high-speed transients occur at random during an otherwise slow rate-of-change phenomenon, the oscilloscope sweep could be made to trigger off only during the transients and rapidly fly back to the original position to record the slow part. The use of timing markers is mandatory to achieve the proper time perspective when studying the recording.

The effects of a heavy load on the performance of a synchronous motor is shown in Fig. 3 and 4. The oscillograms show the starting current in the motor from the in-

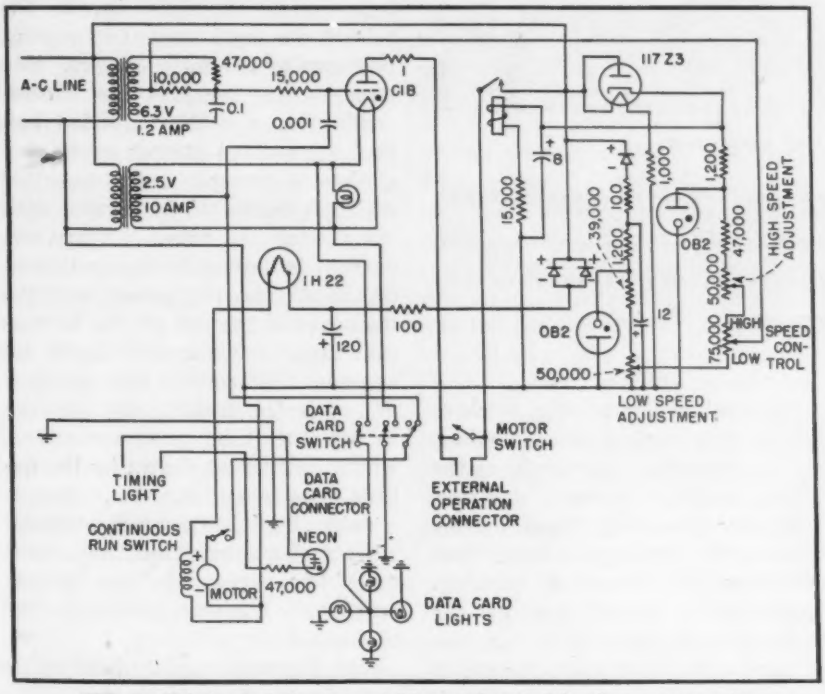

FIG. 1—Circuit of electronic variable-speed-control for the camera motor

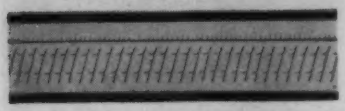

FIG. 2—Top trace—use of film travel as time base. Bottom trace—time base across width of film

FIG. 3—Motor start

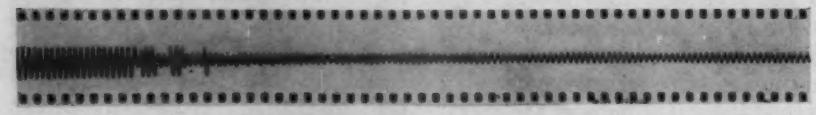

FIG. 4—Motor starting current

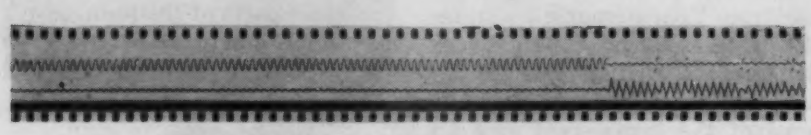

FIG. 5—Top trace—voltage across fluorescent tube. Bottom trace—current through circuit

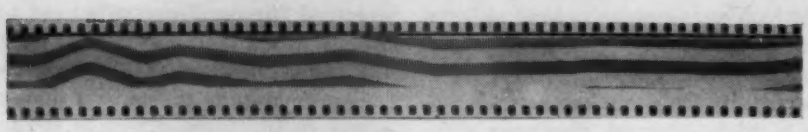

FIG. 6—Oscillator frequency drift

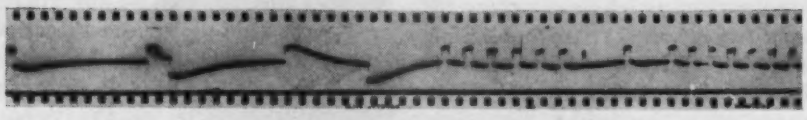

FIG. 7—Output of OB2 with varying load

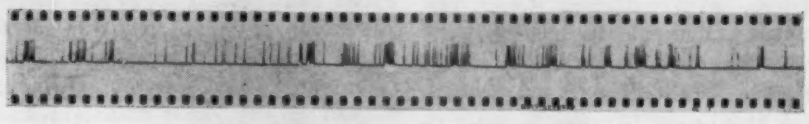

FIG. 8—Output of Geiger-Muller counter

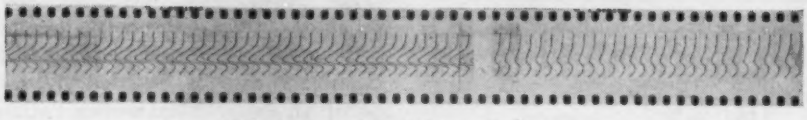

FIG. 9—Potential of frog sciatic nerve

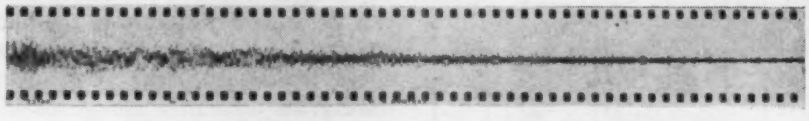

FIG. 10—Reverberation of sharp sound in closed room

stant the switch is turned on to the time that the motor has reached its synchronous peed.

Figure 3 is a single-frame photograph and, although the oscillogram provides some indication of the transients that occur, it is not possible to analyze the phenomenon unless a series of pictures of sections of the overall characteristic is taken.

The oscillogram of Fig. 4, made by the first method of continuous-motion recording, clearly shows the heavy starting current and the automatic switching from starter winding to running winding. This switching and subsequent hunting, visible as a modulation of the motor-current amplitude as the motor builds up enough torque to carry the load, can easily be timed.

Timing markers are unnecessary since each current cycle represents 1/60 of a second. Figure 4 shows that the motor switches to the starting winding 4 times in ½ second because of the heavy load. After the last switching occurs, the motor armature hunts for approximately 3 more seconds before stability is reached. The total elapsed time from the instant of switching on the motor to the time of stability is approximately 4 seconds.

Fluorescent Lamp Analysis

Another application of the oscilloscope and continuous-motion camera in the electrical industry is illustrated in Fig. 5. This oscillogram shows the starting voltage and current characteristics of a fluorescent lamp fixture. The simultaneous recording of voltage and current was obtained by the use of a 5SP dual-beam cathode-ray tube. In Fig. 5, the upper trace represents the voltage across the fluorescent tube and the lower trace represents the total current drawn by the fixture. Again, film motion provides the time base.

The two luminescent spots on the tube screen were positioned in a horizontal line to obtain the proper time relationship between voltage and current in the recording. When the switch is turned on, a voltage immediately appears across the tube and a small amount of current is drawn by the entire fixture. The lamp fixture contains the fluorescent tube, a series-inductive ballast, a gas-filled starter containing a bimetal element, and a capacitor which is connected in parallel with the starter and tube. At first the current is limited by the resistance of the starter, the ballast, and the filaments at the end of the fluorescent tube. After approximately 1.4 seconds, (determined from number of 60-cycle peaks) the voltage across the tube suddenly drops, while the current drawn by the fixture rises to a high value. This is caused by the heated, bimetal starter short-circuiting the capacitor. The current is now limited only by the filaments and the inductive-ballast.

The filaments rapidly heat up as the bimetal in the starter cools.

After another 1/10 of a second, the bimetal cools sufficiently to contract and unshort the capacitor. This causes the current through the inductive ballast to drop, and the collapsing magnetic field causes a resonant voltage surge to appear across the capacitor and tube, as indicated by the first voltage surge-transient in the oscillogram.

During the next ½ second, about 5 more voltage transients occur, corresponding to flickers in the tube, until the fluorescent tube finally starts and remains on. The end of the recording shows a constant voltage being maintained across the tube, and the current, which is limited now by the ballast and the resistance of the gas in the tube. The slope of each peak of the voltage characteristic is the result of the charging and discharging of the capacitor during each cycle.

Such a recording provides the lamp manufacturer with an excellent means of evaluating the action of the gaseous starter, the tube characteristics and the optimum constants for the ballast and capacitor. Since the life of a starter and fluorescent tube depends to a great extent on the number of times that starting occurs, it is of advantage to be able to study these transients in detail.

Frequency Drift

A method of recording oscillator drift by time is shown in Fig. 6. The oscillogram was obtained by a variation of the second method of continuous-motion photography. The recurrent sweep of the oscilloscope was locked to a standard frequency and the output of a drifting oscillator was connected to the Z-amplifier input. The sweep appears as a line across the film with a portion blanked out by the drifting oscillator signal.

If the oscillator frequency and phase are constant with respect to the standard frequency, the blanking will occur at the same point and appear as a straight path along the length of the recording. Notice how the oscillator drifts rapidly at first and then becomes relatively stable. A frequency-drift record such as this can be extended to over eight days on a 1,000-ft. magazine.

The camera provides a means of obtaining voltage time curves of power lines, power supplies, voltage stabilizers and regulators. The output voltage of an OB2 gas regulator tube is shown in Fig. 7. This characteristic was obtained by rapidly varying the load on a regulated supply from 0 to 10 milliamperes. From a curve such as this, the voltage recovery time of a voltage regulator may be determined for either rapid or slow charges in load.

Nuclear Physics

One of the simplest applications of the camera and oscilloscope is to record the output of a particle counter tube. Figure 8 shows an oscillogram of the output pulses of a gamma-ray counter connected to an oscilloscope. The random nature of the pulses and the apparent showers of cosmic rays is recorded. By running the film faster or by using the oscilloscope-sweep recording method, the pulses can be further separated, and the number during any time interval can be counted by using a time-marker track.

Biology and Physiology

Figure 9 is a typical biological recording showing the action potential of a frog's sciatic nerve in response to electrical stimulation at a repetition rate of 100 per second. An electrical-pulse stimulator was used to stimulate the nerve and simultaneously initiate the driven sweep of an oscilloscope at a pulse repetition rate of 100 per second. The film was run at about 3 inches per second, each successive reaction occurring beneath the other. At the start of the recording a portion of the nerve had been dipped into a powerful nerve poison and the reaction of the nerve to the stimuli gradually diminished.

The bottom portion of the recording shows the diminished response caused by poisoning of the nerve. Actually, the entire recording occupied about 100 feet of film so only small portions of the beginning and end are shown. The trailing edge of the stimulating pulse can be seen at the left of each sweep. The recording was obtained at the Columbia Medical Center in New York City with the permission and kind assistance of Dr. H. Grundfest.

Applied Acoustics

Recently, methods have been tried to teach the deaf to see sounds by sight-reading of patterns on luminescent screens. An extension of this method to record these patterns on photographic paper is an obvious consideration and perhaps this will some day lead to musical libraries for the deaf.

With an oscilloscope and continuous-motion camera, acoustics design engineers now have a new means of observing the location and measuring the duration of sound reflections from walls or objects in auditoriums or sound studios. Measurement of reverberation time is one of the difficult problems with which the acoustics designer must cope.[3] Usually the reverberation time is calculated mathematically by measuring the absorption surfaces of every unit in a room and applying acoustical absorption coefficients to these measurements, including them all in a formula. Some designers make use of tables and nomographs to simplify these calculations.[3]

A continuous recording showing the reverberations in a closed room caused by a sharp sound impulse is shown in Fig. 10. The complete sound decay is not shown because of lack of space. As applied to the problems of acoustic design the reverberations may be picked up by a very directional microphone, and the recording would then show the amplitude and location of the source of most echos. Proper placement of sound damping materials is then facilitated and an over-all reverberation time recording may be made.

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Designing INDUSTRIAL

Electronic computer is adjusted to simulate an industrial operation and its control. Engineer then manipulates system to determine optimum design. To simplify computer construction and increase speed very fast time scales are used in computing circuits

By GEORGE A. PHILBRICK
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USE OF ANALOGS makes it possible to experiment readily with devices or phenomena under changes of scale or after transformation of their variables. All models, whether they are the small-scale replicas used by civil engineers, model airplanes in the wind tunnels of aerodynamic engineers, miniature boat hulls in the towing tanks of naval architects, or the equivalent circuits used by acoustical engineers to study microphones, are analogs. Dynamic analogs can be highly complex assemblies such as differential analyzers, abstractions such as mathematics itself, or direct simulations of the process.

The great advantage of analogs as devices for solving engineering problems is that they are simple. Electrical analogs of mechanical, thermal, or other systems can be assembled and adjusted quickly and easily. For example, in designing a pneumatic control, the analogous electrical network of resistors and capacitors of Fig. 1A was built. As a suitable design evolved from experiment a more formal network was constructed. Finally, after experience in the laboratory under many control circumstances, the actual pneumatic control of Fig. 1B was built. Much time and costly machining were saved using the easily modified electrical analogy.

To facilitate making electrical analogies and to perform the broader functions of analog computers in problems dealing with automatic controllers, the Analaut has been developed. It is a flexible electronic instrument for study and demonstration of regulatory systems such as industrial process controls, servomechanisms or position followers, navigational controls, and stabilizers for power plants.

Designing Controllers by Analogs

As long as a process remains in the steady state its analysis is relatively simple. About two decades ago engineers in the process industries, particulary those concerned with instrumentation, became concerned with the dynamic nature of their processes and equipment, especially under automatic operation. Owing to the complexity of such problems, early studies were empirical. Mathematical analyses and syntheses of idealized systems were made. Hydraulic analogs of thermal systems were built from which transient behavior could be studied readily by direct measurement.

Beginning in 1936 the writer developed a complete computational Automatic Control Analyzer based on interconnected high-speed models of both process equipment and its associated controller, which took the form shown in Fig. 2A. Different masks depicting the processes and controls being studied were superimposed on the panel to facilitate visualizing the system; the in-

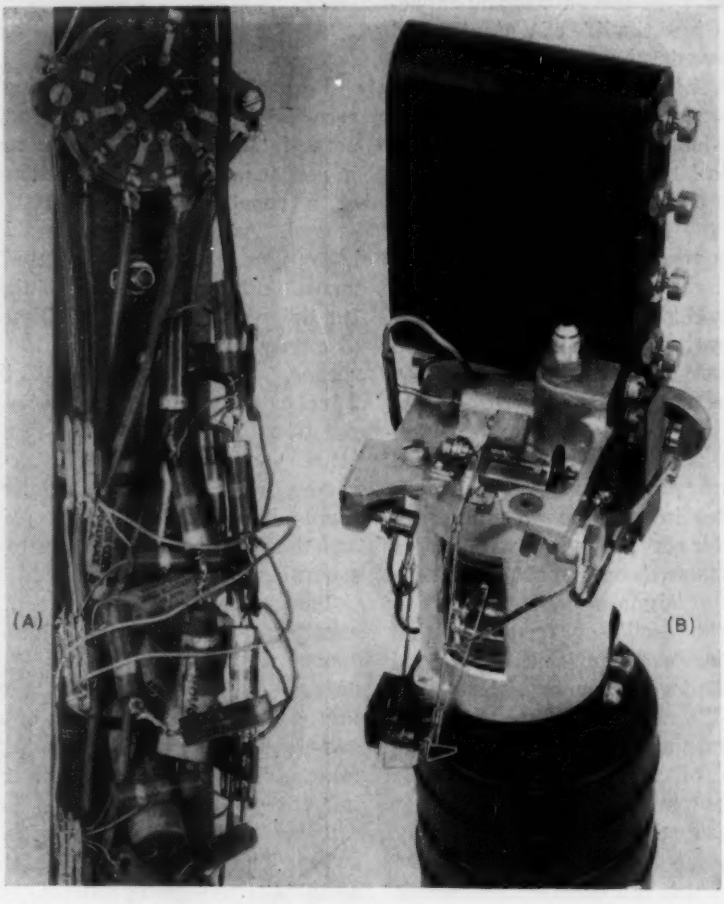


FIG. 1—Electrical analog (A) simplifies design of pneumatic controller (B)

CONTROLLERS By Analog

strument is still in use. The same basic technique, developed to a higher degree, is employed in the modern instrument shown in Fig. 2B. It is used for designing controls and also for predicting the necessary type of control for a proposed installation and the adjustment for optimum performance of complex systems.

Whereas controllers can be designed by mathematical analysis provided the system is not prohibitively complex or by testing in the completed plant if adjustments to the system can be made safely and economically, it is simpler to represent the closed control-process loop by an analog. The heavy lines of Fig. 3A show the loop whose properties are to be studied; the rest of the diagram shows the elements of the analog analyzer. The control manipulates the plant input m in recognition of the unbalance u so as to cause the regulated variable v to follow its desired value v^*, thus reducing the absolute value of the unbalance u to a minimum near zero. All the variable and parameters in the analog are the counterparts of those in the actual plant.

In the analog computing system, the controller and the plant are represented by electronic model assemblages, a basic circuit of which is shown in Fig. 3B. The essential loop variables are transformed into measurable voltages, each of which can be related to the corresponding plant variable by an appropriate scale factor such as pounds per square inch per volt (to convert to pressure in a pneumatic control). For repesenting the desired value there is a manually adjustable steady component and an optionally inserted variable component for disturbing the system. The flexibility of the instrument permits comparing controlled and uncontrolled responses of the simulated system, studying hysteresis and excursion limit effects, inserting conventional regulating functions with proportional, derivative, integral, and second integral effects, and inserting special features from external circuits. Response of the analog is determined by disturbing it with a recurrent pulse and observing the transient on an oscilloscope. The time scale of the analog is made short so that the loop will have returned to equilibrium before the next pulse and so that the computing elements, especially the capacitors, can be conveniently small. The disturbance can be inserted at any desirable point in the loop.

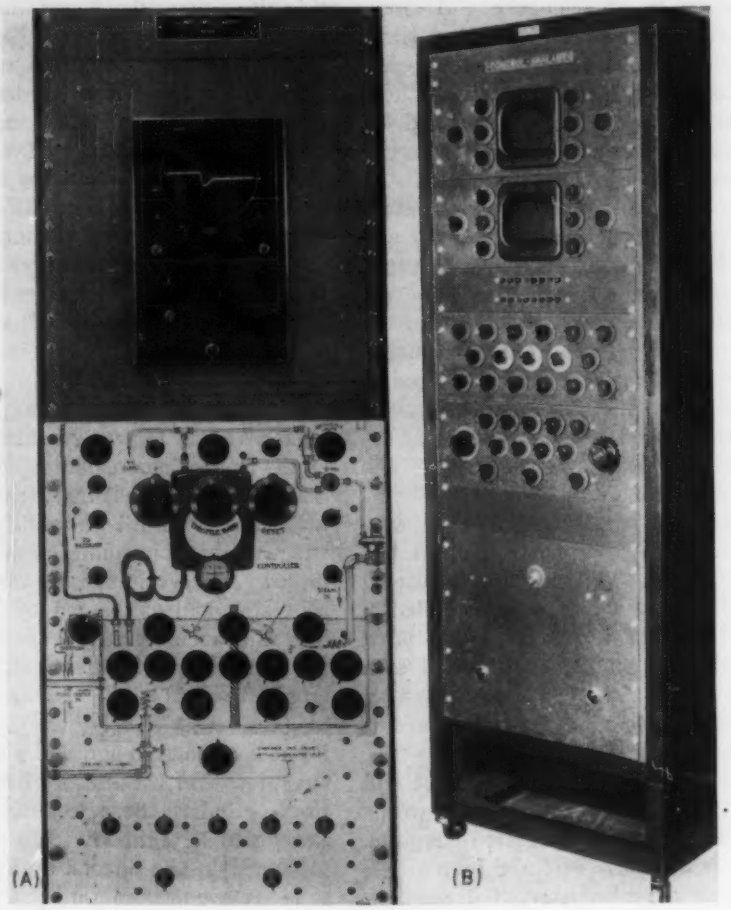


FIG. 2—Circuits of analog computer simulate plant and controller

Usually the variations around the simulated loop are displayed as functions of time on the oscilloscope, with suitable timing markers if necessary. However, by plotting one variable against another parametric plots of great interest can be obtained. Figure 4 shows curves plotted against time, and a parametric curve (for a more complex system) by way of comparing the two types of displays. The parametric method shows the stability and phase relations among significant loop variables.

With such an analog of the process an analog of the appropriate controller can be developed and its suitability observed from the transient response obtained. By manipulating plant or control parameters that are likely to vary during operation, critical conditions can be found and evaluated. With this information the control is practically designed. The fast operating time of the analog permits observing the complete transient response as an adjustment is made, so that a com-

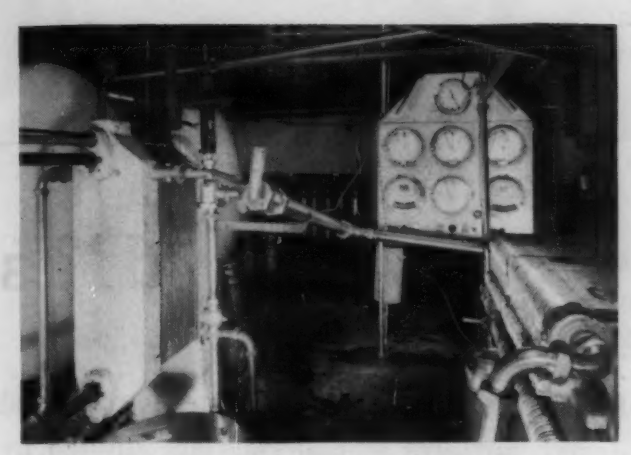


FIG. 5—Control for heat exchanger in this pasteurizing plant was designed by means of electrical analogs

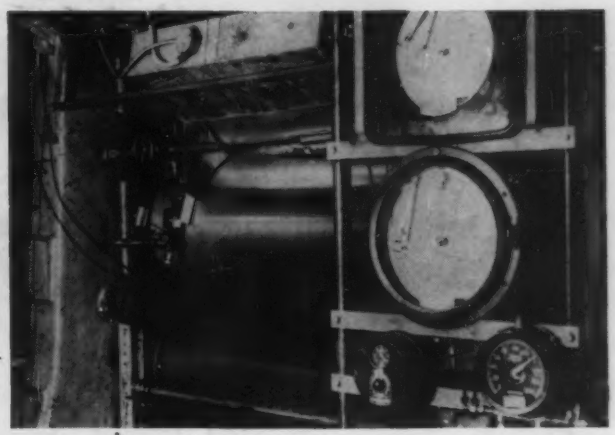


FIG. 6—Floating thermometer head on plastic calendering roller actuates automatic process controller

on the amplitude of the input, its period, and the time constant of the integrator. Other types of computing networks require other techniques for calibration and adjustment, but this example illustrates the simplicity of the methods.

The combinations possible with this basic circuit provide a powerful general technique for constructing computers and control analogs. Most dynamic conditions can be reproduced with this circuit and combinations of passive networks. For a small project, or for initial experimentation, the basic circuit using batteries is especially appropriate because well-regulated power supplies are unnecessary. As used in the control analog computer, common power supplies and auxiliary switching and calibration circuits are necessarily added to the basic circuit.

Industrial Applications

The first step in using the analog computer for designing an automatic control for an industrial plant or process is to reduce the actual system to its elecrical model. In many processes it is possible to recognize the electrical analogs from the equipment and to compute parameters from known data or by simple tests. Distributed parameters can usually be represented to useful accuracies with a few lumped sections.

As mentioned above, if a direct approach is not feasible the dynamic response of the plant can be determined by introducing a known disturbance at the input or manipulated variable and observing the disturbance produced at the output or regulated variable. The plant must remain in a sufficiently undisturbed condition, aside from the intentional disturbance, or the measurement must be repeated often enough to eliminate random effects. Where the response depends on the condition of the load or there are other nonlinearities, a series of tests may be necessary. The record of plant response is then duplicated to a much faster time scale on the control computer, with especial attention to duplicating delay and the initial portions of the response. Once the plant response has been provided in the analyzer, the appropriate control can be quickly determined.

Two typical problems illustrate more specifically how the analog method of designing controllers is carried out in practice. Figure 5 shows a portion of a high temperature pasteurizer; the main heat exchanger is at the right and the instrument panel in the near background. Several interlocking controls are included in the plant to assure holding every drop of milk at a maximum temperature for a minimum interval, avoiding overheating. The crucial regulation problem is to control the hot water temperature in the final milk heater stage at a point chosen for its significant relation to the milk temperature by manipulating a steam valve elsewhere in the system. Under manual operation with water replacing the milk to avoid accidents, a record was made of the temperature variations resulting from a sudden known change of the steam valve. From this information the settings for a proportional derivative-integral control were determined on the analog computer. High performance was obtained from the predicted settings and further adjustments were unnecessary.

In another type of problem the crucial regulated variable was the surface temperature of the central roll of a plastic calender. The temperature was measured electronically by the floating head shown in Fig. 6 and recorded on a self-balancing capacitor bridge instrument. The manipulated variable was steam pressure under control of an auxiliary or cascaded regulator. By making a manual change in the steam pressure, the plant response was obtained on the temperature recorder. The analog of the plant was then set to duplicate this response and several control methods studied. The best type control mechanism thus determined was installed and set to the predicted dynamic adjustments, giving satisfactory control immediately.

Besides providing a design and operating tool in the field of automatic control, this type of analog has also proved useful in instructing plant personnel and as a college lecture room demonstrator and laboratory test set. Acknowledgement is made to the engineers of The Foxboro Company for whom the early developments of these techniques were made, and to Prof. J. A. Hrones of MIT for encouragement in their application to the pedagogy of automatic controls.

plete study of a system can be completed quickly.

Basic Circuit

For special purposes the analog might be arranged differently than the one described here, but the same basic circuit can be used. Most of the complete analog system is based on conventional electronic techniques and so need not be reviewed. However, it should be pointed out that, of the possible mediums for building analogs, the convenience and flexibility of electronic circuits makes them excellent for experimental purposes. If one stays well above the noise and drift thresholds, there is no practical limit to the precision that can be obtained if the needs justify the effort. At the opposite exreme, tube noise can be employed for random excitations where statistical evaluations are to be made.

Figure 3B shows a useful general-purpose circuit for use in electronic analogs. Considered as an amplifier, the circuit is directly coupled for handling direct current but can operate to frequencies that are high compared to the fundamental frequency employed in the disturbance. The input impedance as seen from e_1 is very high. The internal impedance of the circuit is also relatively high so that for reliable results substantially no current can be drawn from the output by the load. Thus, because no current can be drawn at the output e_2, the circuit is usually followed by another of the same kind.

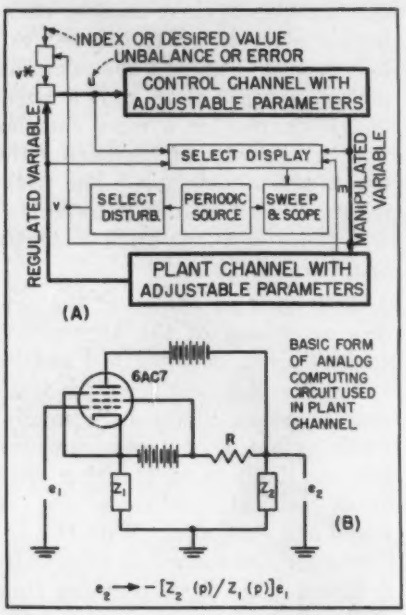


FIG. 3—(A) Block diagram of automatic control computer, and (B) basic circuit of used in the analog computer elements

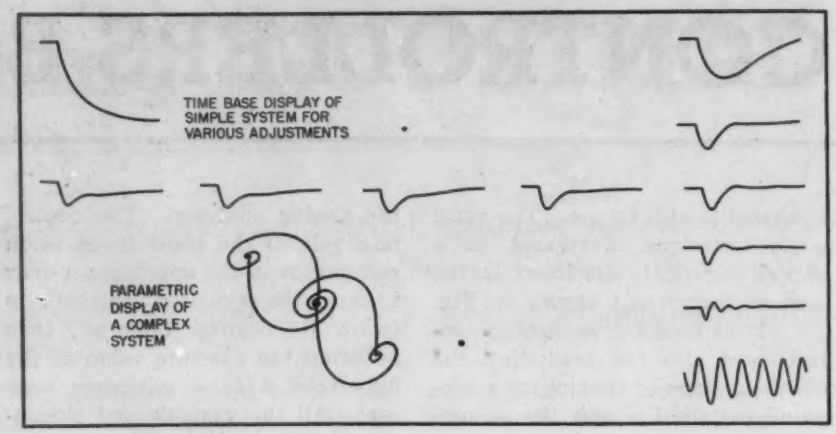


FIG. 4—Reproduction from oscilloscope tracings show how optimum response of plant can be determined by systematic adjustment of various controller adjustments

A fixed source of screen excitation is provided, giving constant gain to zero frequency. The same voltage source provides a reverse current mode of operation in the computing portion of the circuit. Dropping-resistance R is chosen near the average effective d-c plate resistance of the tube. A peculiarity of the circuit is that there are no paths from the tube electrodes to ground other than those through the elements Z_1 and Z_2, thus the currents through these elements are equal and opposite. As the grid voltage approaches cutoff, current circulates through Z_1 and Z_2 in that order, making the output e_2 positive. At the opposite extreme, the current circulates in the reverse direction making e_2 negative. Because the voltage across Z_1 follows e_1, the output e_2 is dynamically related to e_1 in a manner dependent almost entirely on the values of Z_1 and Z_2.

If Z_1 is purely resistive, the current in Z_2 corresponds to the input voltage e_1. This property is useful in various ways; for example, Z_2 can be the input terminals of a four-terminal filter, in which case the current into the filter is directly manipulable with no expenditure of input energy.

If Z_2 is also purely resistive and equal to Z_1, reversal of sign or "minus one" operation results. With Z_1 and Z_2 replaced by a single linear potentiometer, a distortionless inverting amplifier having a useful adjustment is obtained. With the tap in the center, the gain or transfer function is nearly unity. Deflection of the tap in one direction gives a transfer or gain of G and an equal deflection in the other direction gives a gain of $1/G$.

With Z_1 still purely resistive, if Z_2 is purely capacitive, the circuit is a reasonably good integrator with a time constant R_1C_2. In the control analog computer for which this circuit was developed, the computing interval is typically four milliseconds, so that the time constant of the integrator can be made long compared to the computing time using components of reasonable size. If the elements are reversed the circuit is a differentiator. In fact there are numerous dynamic characteristics that can be obtained using different combinations of impedances for Z_1 and Z_2. The nominal equation for the circuit is given in Fig. 3B.

In operating the circuit, care must be taken to prevent saturation of the tube or components. For example, a typical fast integrator will integrate to a limit in a millisecond with one volt remaining on the input. However, such a device can be tested and calibrated by applying a square wave of about five volts amplitude to the input, with an additive adjustable d-c bias. The bias can be set to bring the effective input level to zero and will keep the output within the limits of saturation. Under these conditions a sharp and straight sawtooth will be produced in the output by a sharp square wave at the input; the amplitude of the output will be dependent

Patterns can be observed visually or photographic records can be made

Catalytic action is a surface phenomenon. Electron diffraction photographs reveal the presence of the very thin layer of material responsible for this action. Lubrication is a function of the surface film. Hence the electron diffraction instrument is important in determining good lubricating films and in controlling processes for their production. In addition, it is useful for studying surface changes on bearings and engine cylinder walls.

Method of Operation

The instrument is mounted on a portable table. The major components are an electron gun that produces the electron beam, an apertured anode that accelerates and positions the beam, a magnetic lens for focusing and positioning the beam on the specimen, the specimen chamber with manipulator for adjusting the position of the specimen, a mechanical shutter for controlling exposures and provided with a fluorescent coating for visual indication of focus, a camera box with fluorescent screen for viewing the diffraction pattern and with space for five 4 by 5 inch photographic plates for recording the pattern, the evacuating system, and the power supply.

Either of two apertured anodes, which are grounded and thus maintained at a positive potential relative to the filament, can be brought into position and adjusted mechanically for proper positioning of the electron beam. One aperture admits a beam of 0.002-inch diameter, the other 0.008-inch diameter.

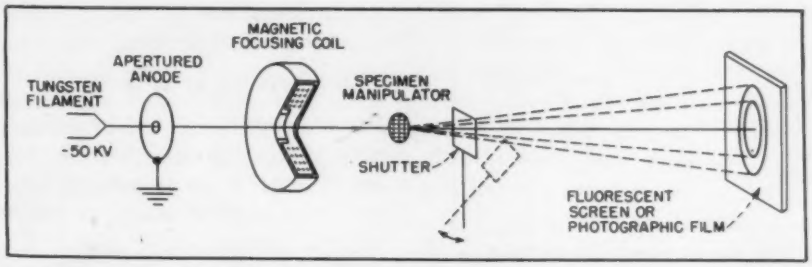
The specimen chamber is about 6.5 inches square by 8 inches deep. Samples are admitted through a door 6 inches in diameter. Three of the faces of the chamber are provided with glass ports 3.5 inches in diameter. These glass windows are interchangeable with metal plates or other accessories. One accessory, a specimen manipulator, is normally mounted on the top port. Another accessory that can be mounted on the front port when required, is an auxiliary electron gun for neutralizing charges that collect on certain specimens.

The specimen, the surface characteristics of which are to be studied, is mounted on the specimen holder. After vacuum has been established and electrons are passing through the apertured anode to form a beam, the operator focuses the beam on the shutter by means of the magnetic lens until, by adjustment of the apertured anode, the unfocused and focused beams coincide. Specimen adjustments are made with the manipulator until a diffraction pattern is obtained on the fluorescent screen. The distance of the specimen from the screen is determined by an accessory telescope, which can be mounted on the specimen chamber.

When a photograph of the pattern that has been focused on the fluorescent screen in the camera box is desired the beam is interrupted by the shutter. A photographic plate is lowered from the upper plate holder by actuating a push button. The shutter is then opened long enough for the exposure. Then the plate is dropped into the lower plate holder by operating another push button.

The evacuating system consists of a mechanical pump and an oil diffusion pump, separately mounted beneath the assembly. A valve seals the chamber from the pumps during specimen changes or loading and unloading of the camera. Vacuum is measured by a thermocouple gage. Time-delay relays prevent premature application of voltage.

The power supply, furnishing accelerating potential to the main electron beam, is adjustable from 20 to 50 kilovolts and is stabilized and ripple-free to better than 0.1 percent. A high-frequency supply furnishes current for the filament of the electron gun. A zero-center instrument indicates any variation of the high potential greater than 0.05 percent.



Elements of electron diffraction instrument show its operating principle

Electron Diffraction for Film and Surface Studies

Crystalline structures of thin films can be determined by diffraction patterns produced when electrons are directed through the material. Surfaces of materials are studied by patterns of reflected electrons. Applications and equipment for the technique are described

By G. A. DOXEY

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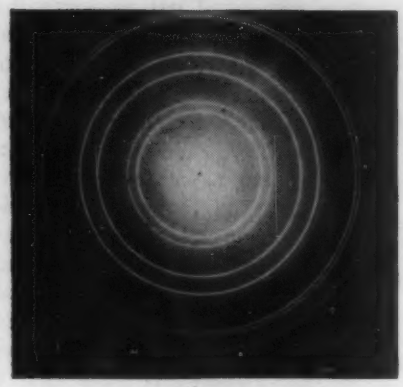
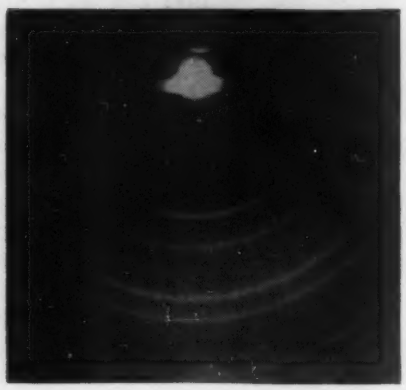


Although oxidation of a magnesium disc was not visible, this reflection electron pattern shows the surface presence of magnesium oxide



Aluminum mounted on a Formvar film to give a total thickness less than 500 Angstrom units produced this transmission electron diffraction pattern

THE ELECTRON diffraction instrument is a research tool designed to aid physicists in observing and measuring conditions on surfaces, or in thin layers, of materials such as metals, ceramics, and plastics. In it a beam of electrons is directed at the material being studied and the resulting diffraction pattern is observed visually on a phosphorescent plate or photographic records are made. This pattern consists of rings, the diameters, intensities, and sharpnesses of which indicate composition, orientation, and atomic arrangement of crystalline material.

Types of Applications

The electron diffraction technique is used for investigating corrosion, catalysts, lubricants, surface deposits, pigments for paints, inks, dyes, graphite, and many phases of metallurgy. The diffraction patterns are similar to those produced by x-ray diffraction. The essential difference is that diffraction patterns resulting from reflecting electrons from the test samples indicate conditions only on surfaces of samples, while diffraction patterns from electrons projected through test samples indicate internal conditions of thin films. X-ray diffraction indicates the condition throughout the entire specimen.

Comparison may be made between electron diffraction patterns obtained by various users of electron diffraction equipment, or with the card index of x-ray diffraction patterns maintained by the American Society for Testing Materials.

The electron diffraction instrument is used in research developing better filaments. It is now generally known that primary and secondary electron emission is a function of the surface conditions. The instrument has been used in the General Electric Research Laboratory in the study of better material for secondary emission. In this case, a magnesium-silver alloy was heated, after which the surface was examined by the electron diffraction instrument and found to be magnesium oxide, which is good for secondary emission.

In studying the cause and prevention of corrosion, it is essential to determine its nature in very early stages. Electron diffraction will detect minute changes and thus will help to identify chemical changes before they are visible under a microscope. By studying corrosion resistance of alloys in different atmospheres, the instrument has aided in selecting the best material for gas-turbine buckets.

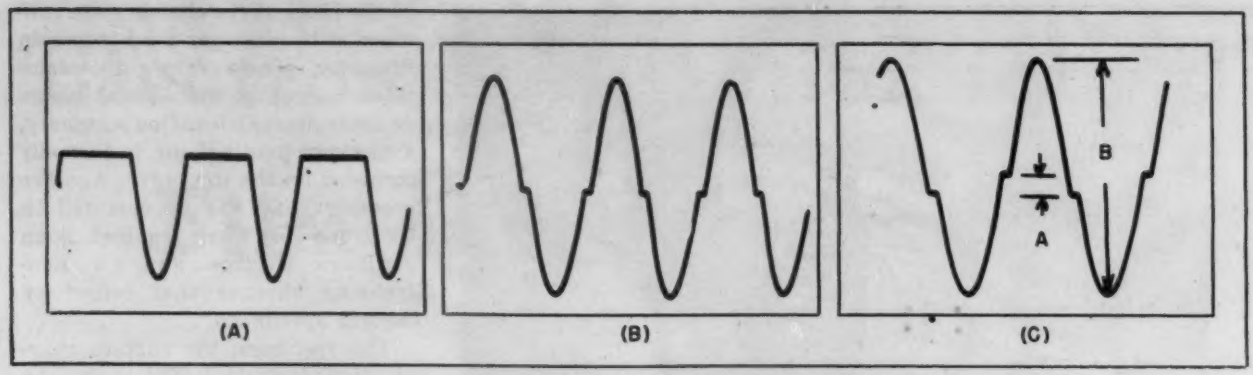


FIG. 1—Clipped sine wave (A); double clipped sine wave (B); double clipped sine wave showing phase shift (C)

Technique for Distortion Analysis

Modification of clipped sine waves by circuits under observation is displayed on a cathode-ray oscilloscope for quick analysis of audio response. Typical patterns are given, and a simple equipment comprising biased crystal rectifiers is described

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DISTORTION in a linear circuit can be separated into two general categories: nonlinear distortion; and frequency distortion. Nonlinear distortion is caused by impedances that are functions of current or voltage. A sine wave introduced in such an impedance will be distorted in waveform because of the harmonics generated. These nonlinear impedances are generally resistive, like those encountered in a tube or crystal.

A sine wave introduced in a circuit containing only reactance will not be distorted in waveform, but may be changed in phase and amplitude. This phase shift and amplitude change may also vary with frequency. Harmonics are not generated in this kind of a circuit, though they may be selectively diminished or accentuated.

Circuits in general have both nonlinear distortion and frequency distortion. The amount and kind of distortion that can be tolerated in a circuit depends on its use. Communication circuits, in which intelligibility is paramount, can have considerable distortion, whereas broadcast circuits should have negligible distortion.

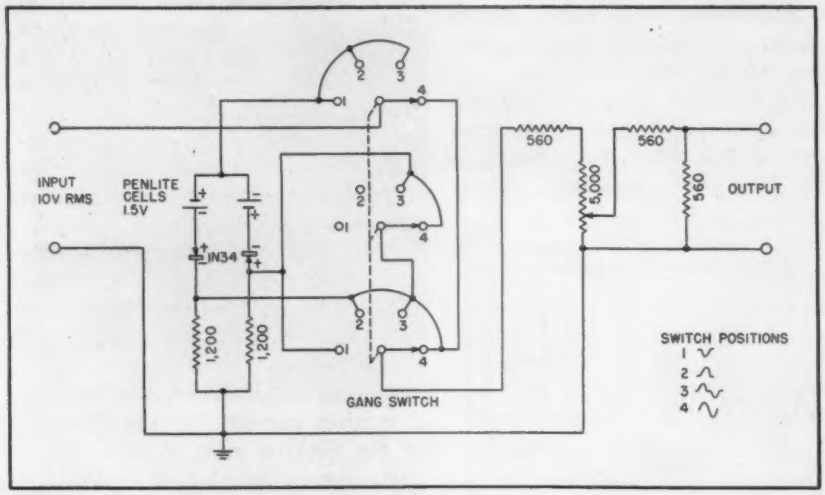

FIG. 2—Circuit diagram of a sine wave clipper with output waveforms for various switch positions indicated

Measurement of Distortion

There are various ways of determining distortion in a circuit in order to indicate its suitability for a particular application. One well-

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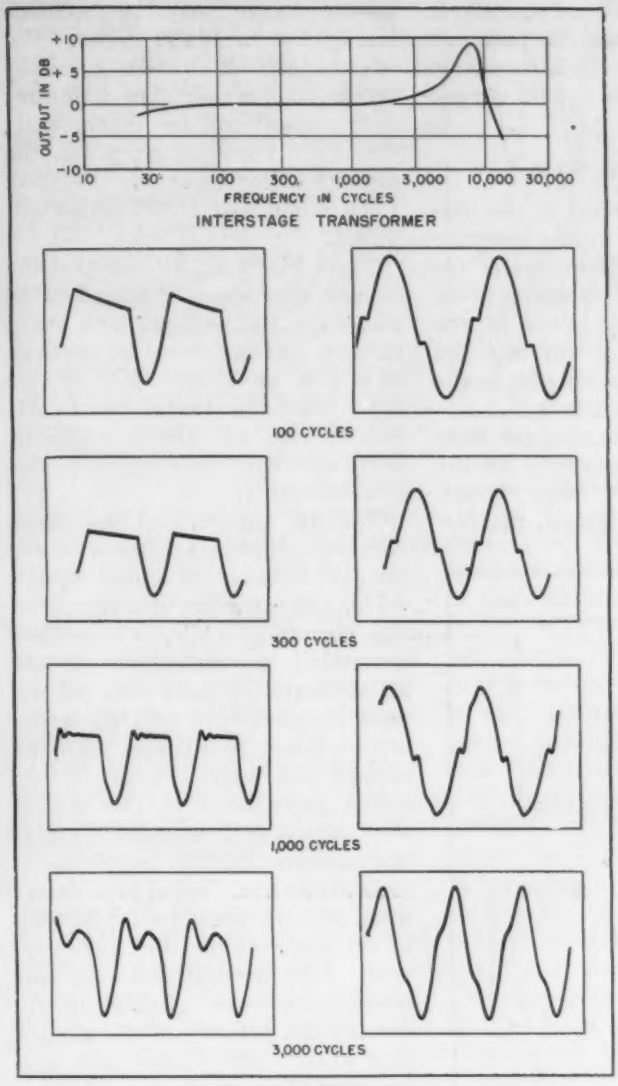
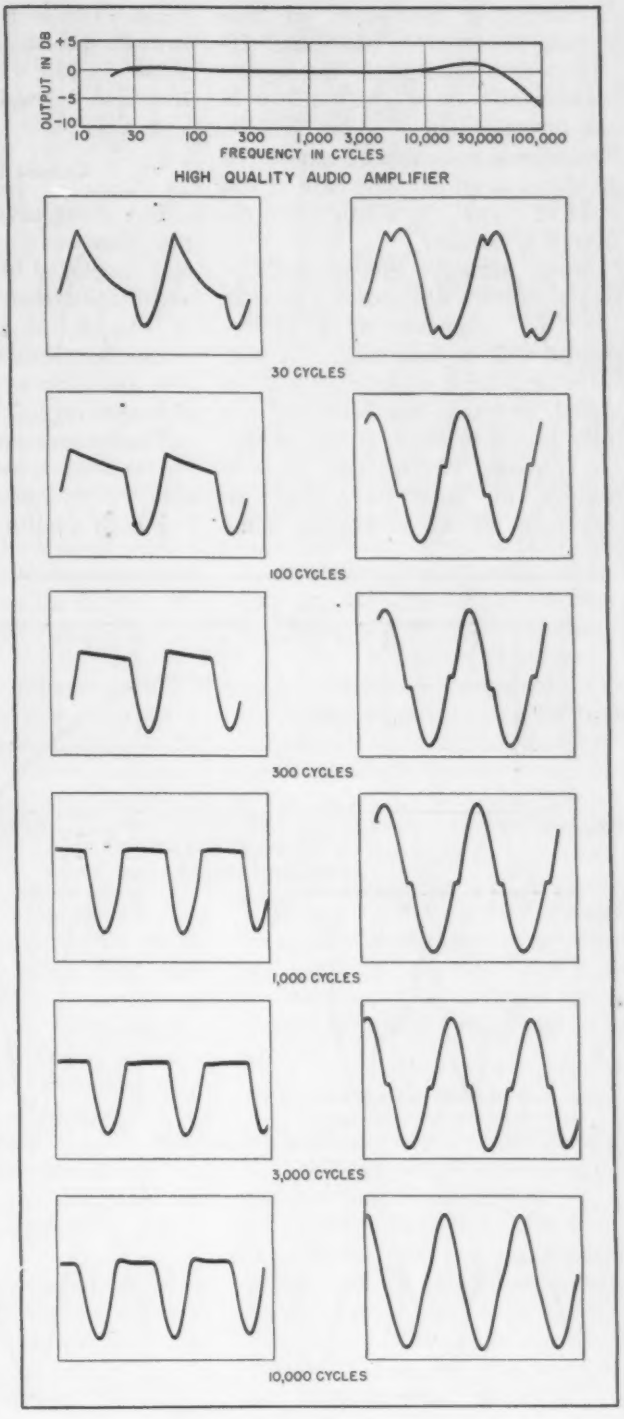


ABOVE

FIG. 3—Response of an interstage transformer in conventional graphic form and by means of clipped, and double clipped, sine waves



RIGHT

FIG. 4—Graph of high quality audio amplifier characteristics with clipped (left) and double clipped (right) oscillograms of response at spot frequencies

known method utilizes the circuit response to a sine wave. Nonlinear distortion is measured by noting the percentage of harmonics generated in the circuit for various frequencies and amplitudes. The effect of reactance is measured by the variation in gain as the frequency is varied.

The interdependence of the two kinds of distortion is not always clearly stated. The harmonics generated by nonlinear distortion will be influenced by the frequency characteristic, so that the sine wave analysis is correct only if either the nonlinear, or the frequency distortion is found to be negligible.

The sine wave analysis is of great utility however, in that definite and reproducible quantities are obtained. In experimental, and developmental work it is sometimes tedious and time consuming.

Standard Waveform Method

A quick and simple qualitative anlysis of a circuit can be made by noting the change in shape of certain standard waveforms. Waveforms with a high harmonic content are particularly suitable for

investigating the effect of frequency distortion in wide-band circuits. One example is the square wave, which is of great utility in the investigation of video circuits. The square wave can be considered to simulate an extreme case of the kind of signal the circuits are required to handle.

Most signals encountered in audio circuits are complex in that they are composed of a fundamental and its harmonics. A test waveform that simulates such a signal, and that has been particularly useful in audio circuit analysis is shown in Fig. 1A. It is a portion of sine wave and is therefore called a clipped sine wave. Two such clipped sine waves can be placed back to back, as shown in Fig. 1B. This waveform has been termed a double clipped sine wave.

Clipped Sine Wave

One great advantage of the clipped sine wave is in the economy and simplicity of its generator for which the circuit diagram is given in Fig. 2. A sine wave of the proper amplitude, is fed into the unit and clipping is done by means of biased crystal rectifiers.

The frequency range of the driving voltage is determined by the kind of equipment being tested. For high quality circuits, the frequency range may be approximately 100 to 10,000 cycles. For communications circuits, it can be 300 to 3,000 cycles. The frequency range need not be continuously variable. For most purposes, the discrete frequencies of 100, 300, 1,000, 3,000, and 10,000 cycles will suffice.

From Fig. 1A it is seen that the clipped sine wave is composed of successive flat portions with sharp corners, interconnected by portions of a sine wave. Analysis of this wave shows it to be the fundamental plus an infinite series of harmonics with the even harmonics predominating.

The flat portion and the sharp corners of the clipped sine wave are similar in shape to a half square wave, and the effect of a circuit on this portion of a clipped sine wave is similar to the effect on the square wave. Square wave experience can therefore be transferred almost intact to analysis with the clipped sine wave.

The asymmetry of the clipped sine wave is of great help in avoiding mistaken analysis due to amplitude saturation. Amplitude saturation is easily noted by a flattening of the peaks of the sine wave portion. Asymmetrical amplitude saturation can be investigated by reversing the polarity of the clipped sine wave. This feature has been useful in the investigation of class-B amplifiers. For the analysis, it is sometimes advantageous to reduce the duration of the sine wave portion by decreasing the ratio of driving voltage to back bias.

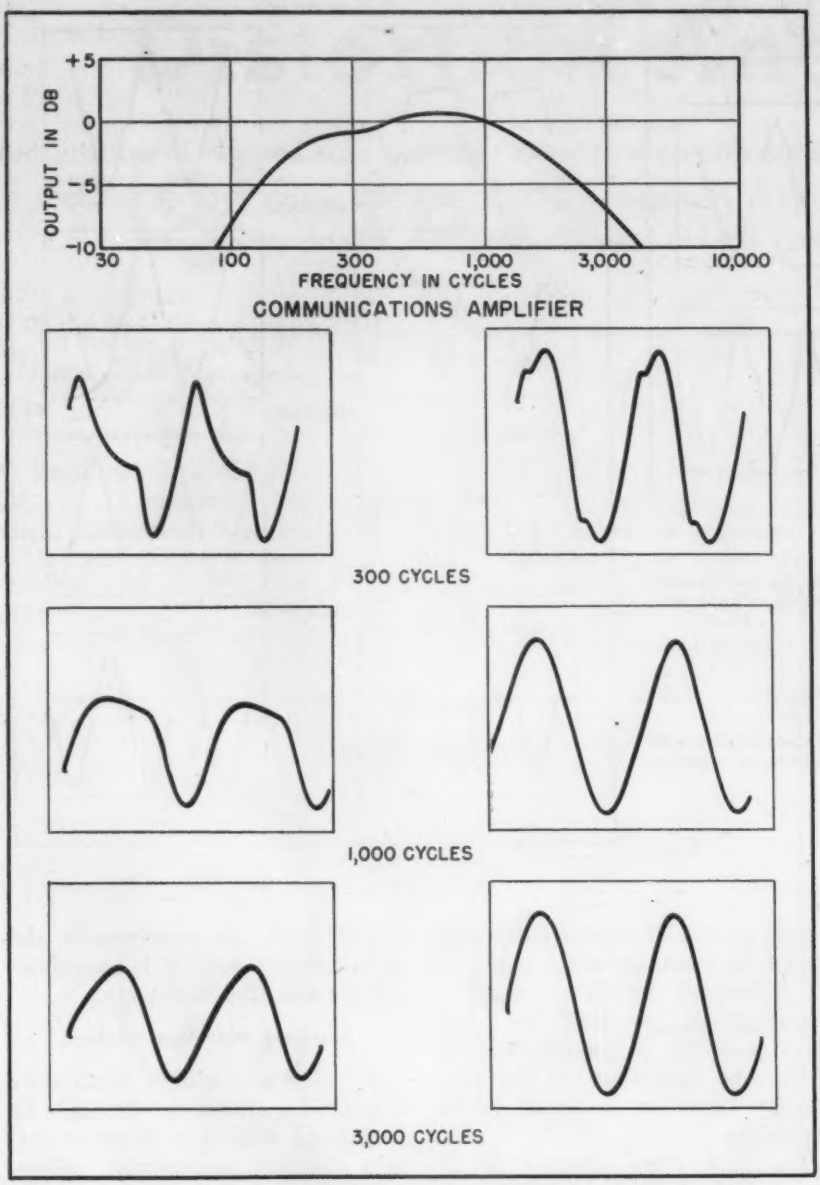


FIG. 5—Response of a communications amplifier. Oscillograms at left show effect on clipped sine waves and, at right, on double clipped waves

Double Clipped Sine Wave

The double clipped sine wave is useful in determining phase shift at low frequencies. It is composed of the fundamental and an infinite number of harmonics, with the odd harmonics predominating. This waveform, (Fig. 1B), is seen to be a sine wave with a small step at the points of zero voltage. Phase shift in a circuit is indicated by a vertical displacement of these steps, as shown in Fig. 1C. The approximate phase shift can be calculated from the following formula

$$\phi = \sin^{-1} (a/b)$$

where ϕ is phase shift; a is the vertical displacement of step por-

tions; and b is the peak to peak amplitude.

It is possible of course, to formulate and plot the effect of various circuits on the clipped sine wave and the double clipped sine wave. For qualitative analysis, however, it is practical to illustrate the effect of several typical circuits on these test waveforms by means of oscilloscope displays.

Interstage Transformer

The frequency characteristic of an inexpensive interstage transformer is shown at the top of Fig. 3. This transformer is essentially flat from 30 to 3,000 cycles, but with a large peak in the response at 8,000 cycles. The effect of this transformer on the clipped sine wave is shown at the left. At 100 cycles, there is sufficient high-frequency response to keep the corners sharp. At 300 cycles, a transient has become evident, becoming larger at 1,000 cycles.

The flat portion of the clipped sine wave is slightly less than a half period. Estimating the number of half waves of the transient on the flat portion and multiplying by two gives the approximate ratio of the transient frequency to the driving frequency. In this case it is estimated to be seven half waves for a 1,000-cycle half period, giving an approximate frequency of 7,000 cycles for the transient. It is interesting to note the correspondence of the transient frequency to the point of high gain on the frequency characteristic. The 3,000 cycle clipped sine wave indicates that the transient frequency has been more closely approached.

In Fig. 3 at the right are shown the effects of the transformer on the double clipped sine wave. The transient is beginning to be evident on the flat portions at 300 cycles. The 1,000-cycle wave is appreciably distorted by the transient, and the steps are practically obliterated at 3,000 cycles owing to dropping high-frequency response.

High Quality Amplifier

The graph in Fig. 4 shows the frequency characteristic of a high quality, multistage, resistance-coupled amplifier. This amplifier is essentially flat between 20 and 50,000 cycles. The series of oscillograms at the left shows the effects of this amplifier on the clipped sine wave. At 30 cycles, the slope of the flat portion illustrates the effect of phase shift. The sharpness of the corners indicates the presence of higher order harmonics. At 100 cycles, the phase shift has decreased and the high-frequency response is still good. The oscillogram for 300 cycles is a good replica of the clipped sine wave, as it is at 1,000 cycles. At 3,000 cycles the effect of high-frequency attenuation is beginning to make itself felt, while at 10,000 cycles high-frequency cutoff has rounded the corners appreciably. The important feature in this analysis is the gradual change in shape of the clipped sine wave over the frequency range. There are no distinct resonant circuits or sharp discontinuities indicated, nor would they be expected in high-quality circuits.

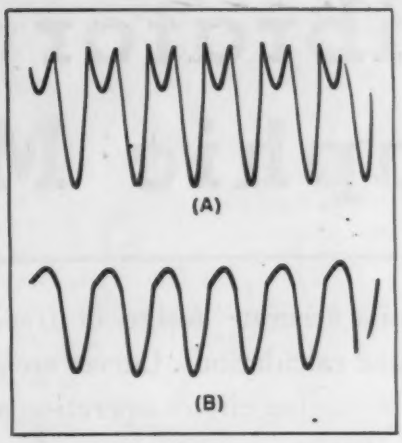


FIG. 6—Clipped sine wave with fundamental partially suppressed (A); and with fundamental partially accentuated (B)

The effect of this amplifier on the double clipped sine wave is shown in the oscillograms at the right. Phase shift, as indicated by the displaced flat portions, is evident at 30 cycles. This characteristic decreases with increasing frequency until it is negligible at 1,000 cycles. At 3,000 cycles the phase shift has reversed direction. Above 3,000 the lack of sufficient high-frequency response tends to obliterate the steps, as shown in the oscillogram for 10,000 cycles.

Figure 5 shows the frequency characteristics of an amplifier used for communication purposes. The response of this amplifier is maximum at approximately 700 cycles. It is down 1 db at 300 cycles, up 1 db at 700 cycles and down more than 7 db at 3,000 cycles. Zero level is taken at 1,000 cycles.

Communications Amplifier

The oscillograms of the effect of this amplifier on the clipped sine wave are shown at the left in Fig. 5. At 300 cycles, phase shift is indicated by the slope of the flat portion, and the lack of high-frequency response by the blunted corners. The oscillogram for 1,000 cycles shows a rise in gain at somewhat less than 1,000 cycles, and the corners are further obliterated. At 3,000 cycles, the effect of a poor high-frequency response is evident. It is interesting to note in this amplifier also, the lack of any tendency toward transients. The clipped sine wave analysis indicates a broadly resonant circuit, with maximum gain at less than 1,000 cycles, and no significant frequency discontinuities outside the pass band.

To the right are the oscillograms showing the effect of this amplifier on the double clipped sine wave. The large phase shift at 300 cycles is shown by the vertical displacement of the flat portions. These steps are increasingly obliterated by the lack of high-frequency response at 1,000 cycles and 3,000 cycles.

Tuned Circuit at Driving Frequency

The examples just given illustrate the ordinary use to which one may put the clipped and double clipped sine wave. The effect of a circuit tuned to the fundamental frequency of the clipped sine wave was not clearly exemplified, and is therefore illustrated. Fig. 6A shows the shape of the clipped sine wave with the fundamental partially suppressed, and (B) with the fundamental partially accentuated. The flat portions have now become concave in A and convex as in B.

When the driving frequency is shifted slightly from that of the tuned circuit these convex and concave portions will be displaced to one side. An example of this effect is shown in Fig. 5 (1,000 cycles, at the left) illustrating the effect of a communications circuit on the clipped sine wave.

Multivibrator Design by Graphic Methods

Simple graphic method permits accurate design of free-running multivibrator circuit, eliminating tedious and repeated calculations. Curves are given for commonly used tubes. All phenomena determining circuit operation are taken into account

By A. E. ABBOT

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THE equation for the semiperiod of the free-running zero-bias multivibrator shown in Fig. 1, as derived from its equivalent circuit, is

$$\tau_1 = \left(R_{g1} + \frac{R_L r_p}{R_L + r_p}\right) C_1 \ln\left(\frac{E_b - E_m}{E_x}\right) \quad (1)$$

where τ_1 = semiperiod of multivibrator
R_{g1} = grid resistance
R_L = load resistance
r_p = plate resistance
C_1 = coupling capacitance
E_b = plate-supply voltage

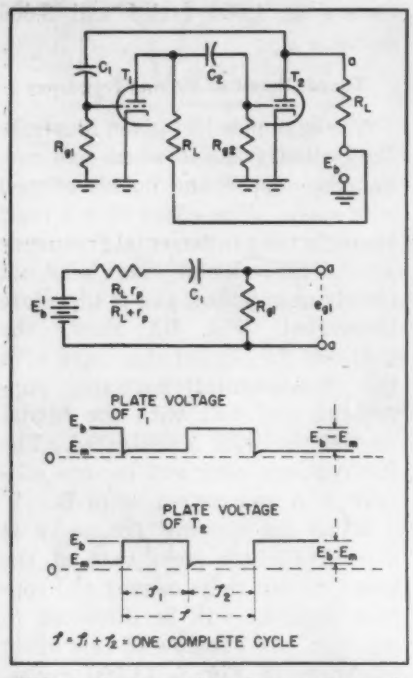


FIG. 1—Basic zero-bias free-running multivibrator, equivalent circuit, and typical time and voltage relations at the plates of the tube

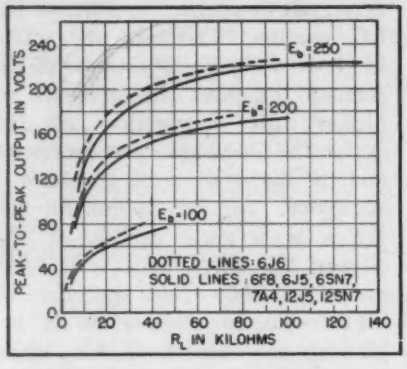


FIG. 2—Variation of output voltage with load resistance for tubes commonly used in multivibrator circuits

E_m = minimum alternating voltage on the plate
E_x = cutoff voltage corresponding to E_b

The subscript 1 denotes those factors pertaining to tube T_1. The various time and voltage relationships in the wave produced are shown also in Fig. 1. In Fig. 2 is given the output voltage E_o of the multivibrator in peak-to-peak volts as a function of load resistance.

The buildup time of the multivibrator, τ_B, is given on the A scales of the nomograph in Fig. 3. This nomograph is based on

$$\tau_B = 4\,(R_L + r_p)\,C \quad (2)$$

The value of τ_B obtained here covers the period required for the voltage wave to reach 98 percent of its peak value.

In Fig. 4 it is assumed that

$$\alpha = \frac{E_b - E_m}{E_x} \quad (3)$$

and α is plotted in this graph against various values of R_L and E_b. Figure 4, therefore, gives a value of α that can be multiplied by the time constant to give the semiperiod. Therefore, Eq. 1 reduces to

$$\tau_1 = \left[R_{g1} + \frac{R_L r_p}{R_L + r_p}\right] C_1 \alpha \quad (4)$$

Figure 5 is a period-versus-frequency chart, which is included to facilitate the determination of the whole period τ when the frequency is given. This enables a simple calculation of fractional periods in the case of an unsymmetrical multivibrator (Fig. 1):

$$\tau = \tau_1 + \tau_2 \quad (5)$$

where τ_1 and τ_2 are the fractional periods.

In Fig. 6 and 7, it is assumed that

$$\beta = \frac{R_L r_p}{R_L + r_p} \quad (6)$$

Therefore, Eq. 4 further reduces to

$$\tau_1 = (R_{g1} + \beta)\,C_1 \alpha \quad (7)$$

In Fig. 6, it is also assumed that

$$\gamma = \frac{R_{g1}}{R_{g1} + \beta} \quad (8)$$

When plotted against R_g, the factor γ permits an evaluation of the effect of the load and plate resistances on the grid resistance. For the value of R_L selected, if R_g is made so high that $\gamma > 0.9$, then it can be assumed that $\beta = 0$. When $\gamma > 0.9$, there is approximately a 10-percent error in the calculation of τ_1; this falls to 5 percent when $\gamma = 0.95$.

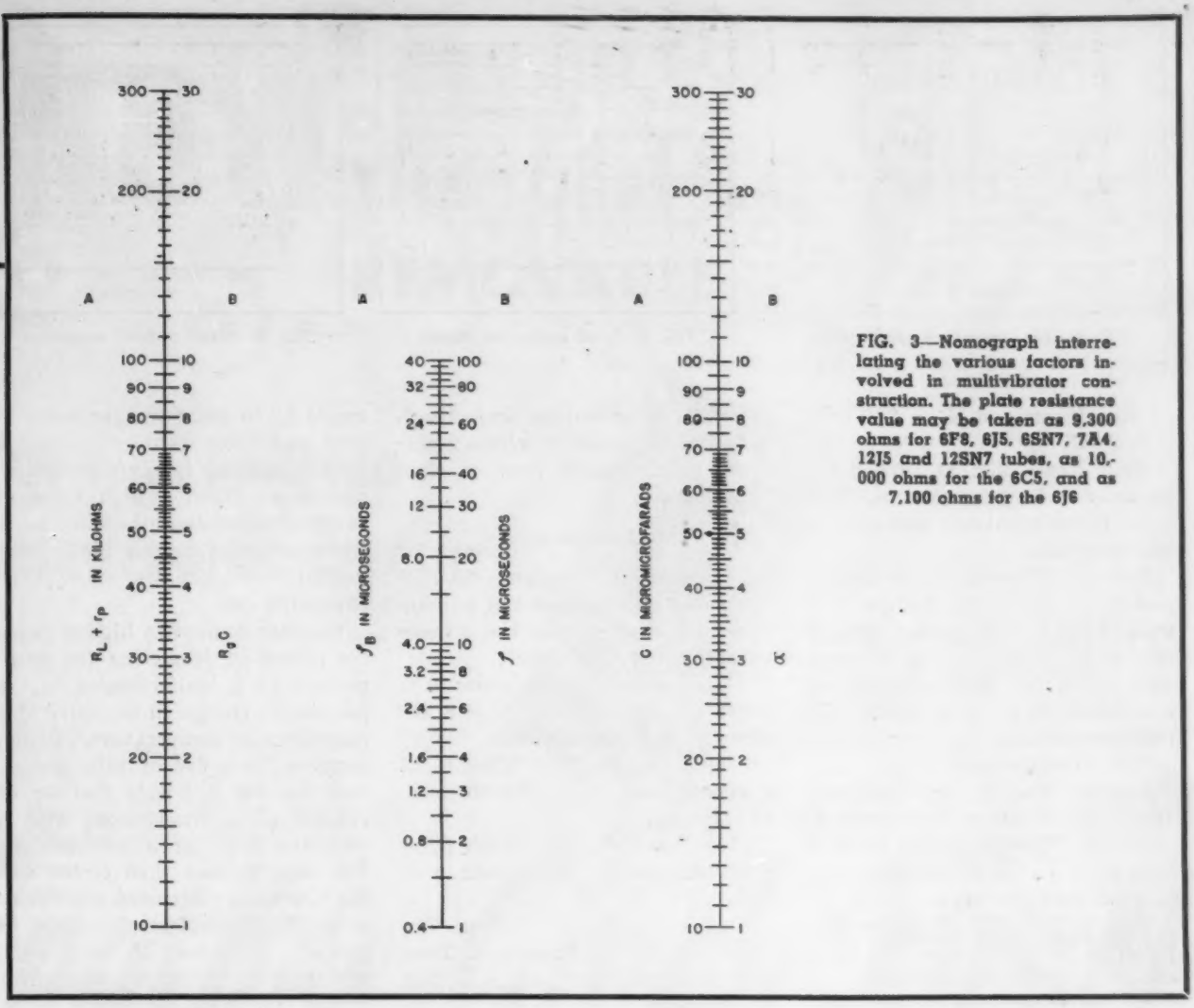


FIG. 3—Nomograph interrelating the various factors involved in multivibrator construction. The plate resistance value may be taken as 9,300 ohms for 6F8, 6J5, 6SN7, 7A4, 12J5 and 12SN7 tubes, as 10,000 ohms for the 6C5, and as 7,100 ohms for the 6J6

Equation 7 reduces to a simple equation

$$\tau_1 = R_{g1} C_1 \alpha \qquad (9)$$

The B scales of Fig. 3 are a plot of Eq. 9, and enable a simple calculation of the fractional period from the time constant and α.

If the conditions of the problem are such that $\gamma << 0.9$ it will be necessary to include the effect of β and use Eq. 7 rather than Eq. 9.

Figure 7 gives the value of β for different load resistances. The r_p selected in this calculation is an average value. With a given voltage swing, there will be a maximum deviation of 11 percent between any possible r_p and this average value.

Example 1

It is desired to design a multivibrator, using a 6SN7 tube, that will have a peak-to-peak output of 190 volts and will operate at a frequency of 30 kc. The pulse width required for triggering purposes is 10 microseconds. The plate supply is 250 volts.

Then $E_b = 250$ volts, $f = 30$ kc, $E_o = 190$ volts peak to peak, and $\tau_1 = 10$ microseconds.

Step 1 (see Fig. 2): When $E_o = 190$ volts and $E_b = 250$ volts, $R_L = 35$ kilohms.

Step 2 (see Fig. 4): When R_L

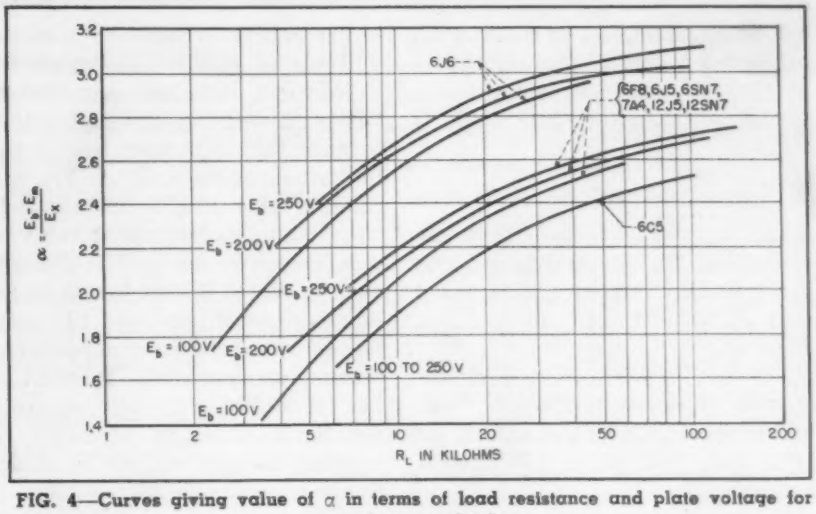


FIG. 4—Curves giving value of α in terms of load resistance and plate voltage for several types of tubes

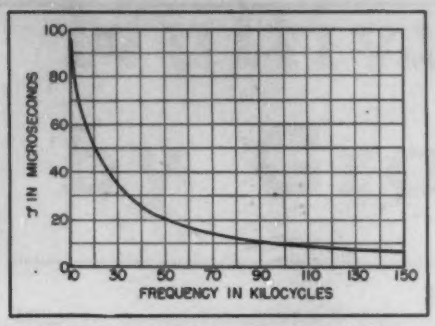


FIG. 5—Time-frequency relationship

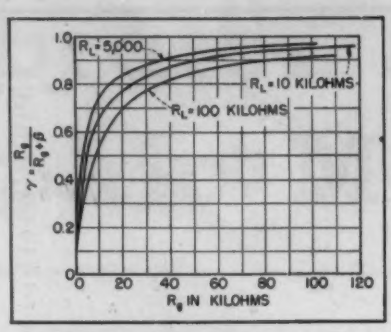


FIG. 6—Load resistance curves

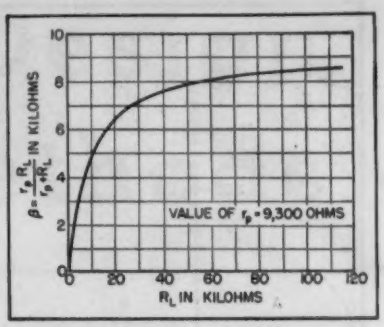


FIG. 7—Effect of load resistance

$= 35$ kilohms and $E_b = 250$ volts, $\alpha = 2.563$.

Step 3 (see Fig. 5): When $f = 30$ kc, $\tau = 34$ microseconds. Then $\tau_1 = 10$ microseconds and $\tau_2 = 24$ microseconds.

Step 4: When $R_L = 35$ kilohms and $R_{g1} = R_{g2} = 0.1$ megohm, $\gamma = 0.93$. Then $\beta = 0$. Using scales B of Fig. 3: When $\tau_1 = 10$ microseconds $\tau_2 = 24$ microseconds, and $\alpha = 2.563$, $R_{g1} C_1 = 10/2.563 = 3.9$ microseconds, and $R_{g2} C_2 = 24/2.563 = 9.35$ microseconds.

Step 5: When $R_{g1} = 0.1$ megohm and $R_{g1}C_1 = 3.9$ microseconds, $C_1 = 40$ μμf. When $R_{g2} = 0.1$ megohm and $R_{g2}C_2 = 9.35$ microseconds, $C_2 = 95$ μμf.

Step 6 (see Fig. 3, scales A): When $R_L = 35$ kilohms and $C_1 = 40$ μμf, $\tau_3 = 7$ microseconds.

A multivibrator was constructed according to the above calculations, with resistor and capacitor values accurate to within 1 percent. Calculated and experimental values of the semiperiod were identical, and E_o differed by only 2 volts.

It is desired to improve the buildup time of the multivibrator output in Example 1 at the expense of output voltage. The conditions of the problem remain the same, except that a lower value of R_L is selected.

Example 2

Let $R_L = 10$ kilohms. Then, by consulting the curves in the same order as in Example 1, it is found that $E_o = 132$ volts, $\alpha = 2.205$, $R_{g1} = R_{g2} = 0.1$ megohm, $\gamma = 0.93$, $R_{g1} C_1 = 10/2.205 = 4.54$ microseconds, $R_{g2} C_2 = 24/2.205 = 10.88$ microseconds, $C_1 = 45.4$ μμf, $C_2 = 108.8$ μμf, and $\tau_3 = 3.51$ microseconds.

The multivibrator was again constructed, using resistor and capacitor values accurate to within 2 percent; results again were in close agreement.

Example 3

It is desired to design a 25-kilocycle multivibrator with a buildup time of 2 microseconds and a pulse width of 15 microseconds.

Step 1 (see Fig. 3, scales A): When $C = 31$ μμf and $R_L = 8$ kilohms, $\tau_3 = 2$ microseconds.

Step 2 (see Fig. 2): When $R_L = 8$ kilohms and $E_b = 250$ volts, $E_o = 119$ volts.

Step 3 (see Fig. 4): When $R_L = 8$ kilohms and $E_b = 250$ volts, $\alpha = 2.11$.

Step 4 (see Fig. 5): When $f = 25$ kc, $\tau = 40.1$ microseconds. Then $\tau_1 = 15$ microseconds and $\tau_2 = 25.1$ microseconds.

Step 5 (see Fig. 3, scales B): When $R_{g1} C_1 = 15/2.11 = 7.11$ microseconds, and $C_1 = 31$ μμf $R_{g1} = 0.228$ megohm. When $R_{g2} C_2 = 25.1/2.11 = 11.9$ microseconds and $R_{g2} = 0.1$ megohm, $C_2 = 120$ μμf.

Limitations

The results of tests on a multivibrator of this design, using resistors and capacitors accurate to within 2 percent, are interesting because they illustrate one of the limitations of the method. The calculated value of τ_1 is 15 microseconds, while the measured value of τ_1 is 13 microseconds. The discrepancy is caused by the low value of coupling capacitance used (31 μμf). At this value, the stray capacitance becomes an appreciable fraction of the total. For extremely accurate results, it would be necessary to subtract the tube and wiring capacitance from the calculated value.

Another solution to the problem would be to use a smaller value of grid resistance, thus permitting a correspondingly larger coupling capacitance. When a high value of coupling capacitance is used, as in the calculation for τ_3, the experimental results are very close to the calculated one.

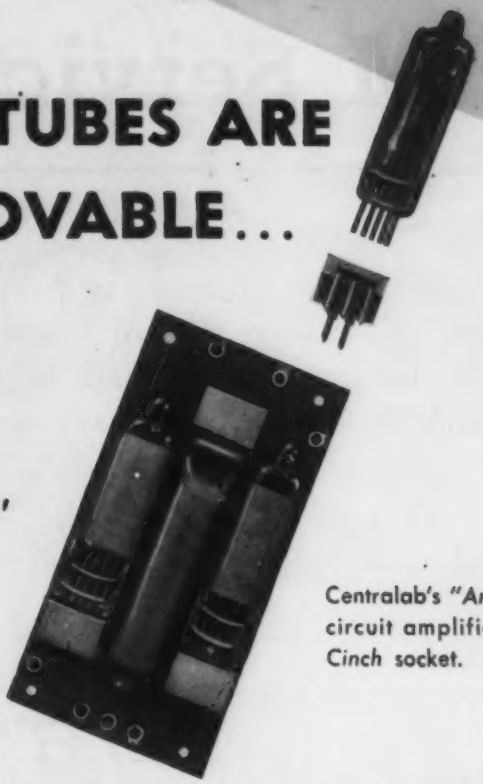
Another somewhat hidden cause for errors in predicting the semiperiods of a multivibrator is the permanent change in the value of a resistor with temperature. To determine the order of this change, each lead of a ½-watt resistor of 102,600 ohms was heated with a soldering iron for a half minute. The resistor was then cooled and the measured resistance was found to be 148,000 ohms, a change of 45 percent. Each lead of five ½-watt, 0.1-megohm resistors was then heated for fifteen seconds. The average resistance change, after they had cooled for a long period of time, was 17 percent. Thus, the process of soldering resistors into a circuit may change the value of the resistor permanently and, consequently, affect the semiperiod of the multivibrator.

To evaluate the cause of the discrepancy in Example 3, the following experiment was made: The 31-μμf capacitor was replaced by a variable mica trimmer capacitor, which was adjusted until the semiperiod was exactly 10 microseconds. The capacitance value under these conditions was 27 μμf. Thus, a 4 μμf error caused by wiring and tube capacitance is responsible for the 3-microsecond error in the pulse width.

The results obtained with the new value of capacitance were: $\tau_1 = 10$ microseconds, $\tau_2 = 26$ microseconds, $\tau_3 = 3$ microseconds, and $E_o = 110$ volts.

NOW THE TUBES ARE REMOVABLE...

IN THE "PRINTED ELECTRONIC CIRCUIT"



Centralab's "Ampec" printed circuit amplifier using new Cinch socket.

Another Cinch First!

SUB-MINIATURE SOCKET for "printed electronic circuit"

. . . insert contact tails through holes in insulation and bend over — socket is mounted, tube lies horizontal to chassis, soldering tails positioned on back of chassis for wiring. These newly designed "self attaching" sockets will revolutionize conventional wiring in chassis applications.

Sub Miniature Socket No. 54 A 13124 *(Reproduced here twice size)*

PATENT PENDING

Co-ordinated with the extensive and exhaustive research of Centralab, CINCH engineering experience now contributes a perfected socket for the "printed electronic circuit." The new sub-miniature socket takes no additional space . . . holds tubes securely in place with high tension contacts of new design . . . permits easy maintenance and replacement of tubes; low loss bakelite provides maximum insulation and minimum high frequency loss. Tube is inserted from either side, the width of the socket equals the length of leads in the tube itself.

Samples and further details on request.

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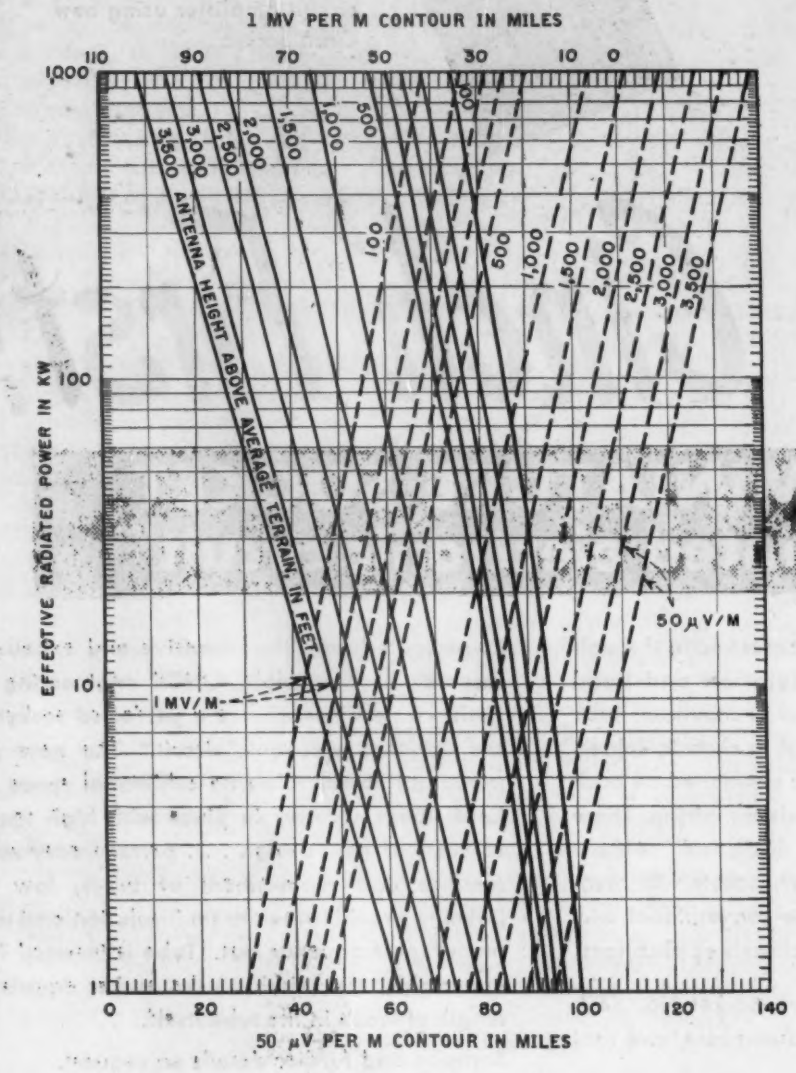
F-M Service Areas

Chart shows approximate distance to 1-mv/m and 50-μv/m contours for effective radiated powers between 1 and 1,000 kw and transmitting antenna heights from 100 to 3,500 feet above average terrain

BY JOHN H. BATTISON
Allocations Engineer
American Broadcasting Co., Inc.
New York, N. Y.



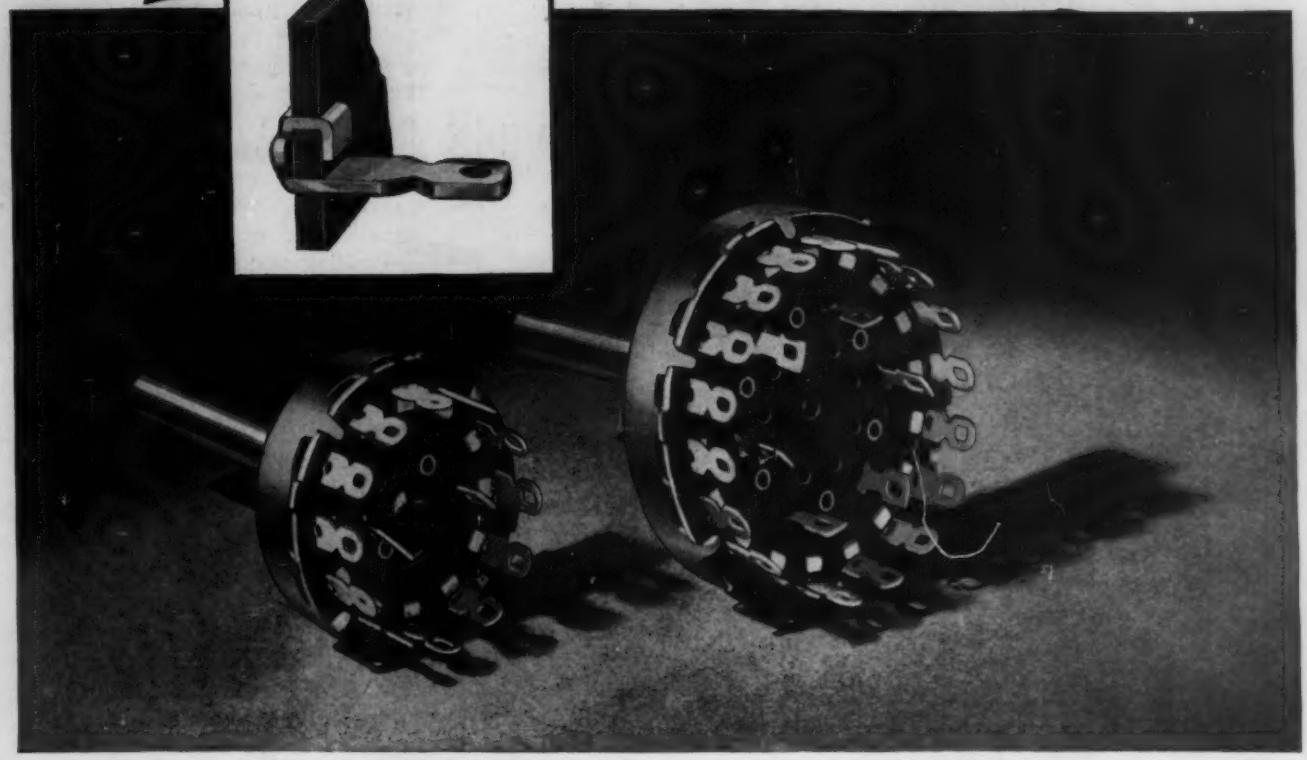
THE accompanying chart, based on FCC data, provides a quick means of determining the approximate service areas of a transmitter operating on any channel between 88 and 108 mc. Distance to the 1 mv-per-meter contour (solid lines) is shown by the upper scale and distance to the 50 microvolt-per-meter contour (dashed lines) by the lower scale, for various effective radiated powers and transmitting antenna heights. Receiving antenna height is assumed to be 30 feet above average terrain.

Using the Chart

To determine the distance to the 1 millivolt-per-meter contour with a transmitting antenna height of 2,000 feet and 20-kw of effective radiated power, enter the chart at the left and, at the point where the 20-kw horizontal line intersects the solid diagonal line labelled 2,000′, read on upper scale 57 miles. To determine distance to 50 microvolt-per-meter contour follow the same procedure, but use the dashed diagonal line labelled 2,000′ and read the lower scale.

If coverage is desired at a given distance, with a known transmitting antenna height, the effective radiated power required may be read to the left of the point of intersection of appropriate distance and height lines. Similarly, should it be necessary to determine the transmitting antenna height required to provide a certain contour with a given power the chart may be entered from the left and the bottom, and the height read from the appropriate solid or dashed line.

This Terminal Won't Pull Off or Work Loose . . .

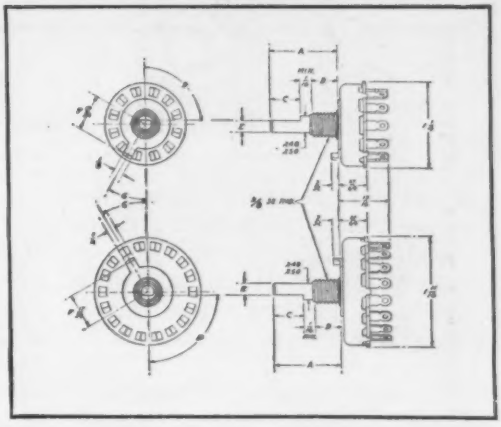


. . . IT'S ONLY ONE FEATURE OF THIS COMPACT LOW VOLTAGE MALLORY SWITCH

The inset at the top of this picture shows how the terminals of Mallory 3100 Switches are doubly fastened by a wrap-around method which holds them tight and secure against damage and at the same time provides them with a smoother contact surface.

What the picture cannot show is that the stator is made of low-loss XXX Phenolic especially selected for good insulation properties at high humidities . . . that a metal web spaced between the terminal contacts improves non-shorting construction . . . that terminals and stator together provide an excellent solder shield.

Small size, of course, is another distinguishing feature of these 3100 Switches, of which millions have been sold to manufacturers of radios, inter-communication systems and test equipment. The larger model, shown above, is 1 1/16" in diameter and has 18 position 20° indexing, embracing one to six circuits. The smaller model, with 12 position 30° indexing, embracing one to four circuits, is only 1¼" in diameter.



For more details, send for Mallory 3100 SWITCH Engineering Data Folder. A wide range of standard stock types is available through convenient Mallory Distributors.

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3100 SPECIFICATION SHEETS

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MALLORY SWITCHES

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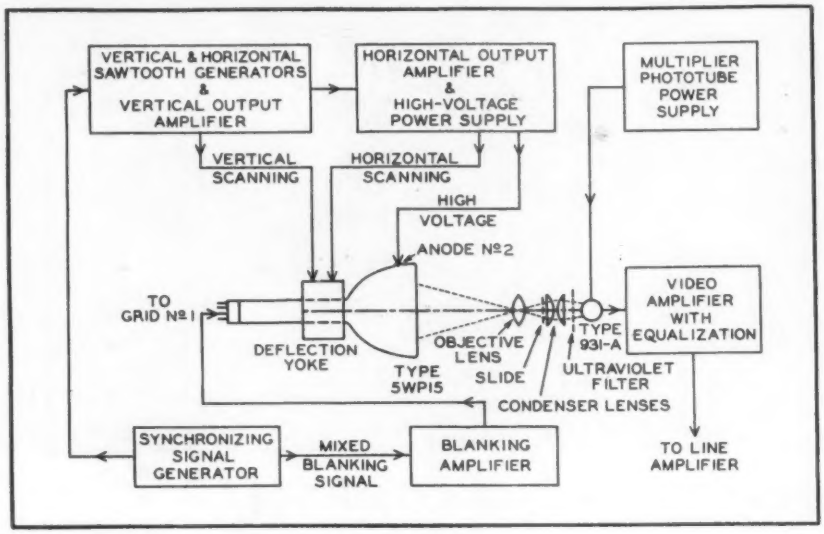
P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

TUBES AT WORK

Including INDUSTRIAL CONTROL

Edited by VIN ZELUFF

Flying-Spot Video Generator 124
Multiple Baby Sitting 126
Versatile Power Supply 126
Phase Meter 142
R-F Heating for Cabinets 152
Carrier Shift Check Meter 162



Video signal generator system for slide transparencies, using the RCA Flying Spot tube

Flying-Spot Video Generator

A NEW cathode-ray tube allows television stations to construct a video-signal generator which permits transmission of station call letters and test patterns from interchangeable slide transparencies or opaque surfaces.

The tube, RCA5WP15, furnishes a small, rapidly moving spot of radiant energy (hence the name) for scanning. It has an extremely short persistence phosphor having a large component of its energy emission in the near-ultraviolet region. The persistence of the ultraviolet radiation is so short that the amount of equalization needed in the video amplifier to minimize trailing in the reproduced picture is small and can be supplied by a single network. As a result, circuits and adjustments are relatively simple.

A video-signal generator using the tube would consist essentially of the Flying-Spot tube with associated power supplies, deflection yoke, and scanning circuits; a lens to project the raster on the subject to be scanned; the subject, a slide transparency, motion picture film, or opaque object; a multiplier phototube with associated power supply to intercept the radiation transmitted or reflected by the subject, and convert it into video signals; and a video amplifier.

The tube makes possible unusual video effects, such as double images —one produced by a slide, the other by modulating the beam of the tube. A block diagram of a video-signal generator arranged for use with a slide transparency is shown. For best results, the objective lens should be a high-quality enlarger type designed for low magnification and preferably corrected for use with ultraviolet radiation.

Suitable filters for absorbing the visible and passing the ultraviolet radiation of the screen are available. The choice of filter is affected by a compromise between the permissible loss of signal output through absorption by the filter and the amount of trailing which can be tolerated, or the extent of equalization needed.

Trailing results from the lag in buildup and decay of output from the screen. As the flying spot moves across a boundary from a light to a dark area of the subject being scanned, the persistence of energy output from the screen results in continued input to the phototube from the light area during the time the dark area is being scanned. Thus, the light area trails into the dark area in the reproduced picture.

Similarly, as the flying spot moves from a dark area to a light area, the lag in buildup of the screen output causes the dark area to trail over into the light area. As a result of these effects, the reproduced picture has an appearance similar to that produced by a signal deficient in high frequencies. It is, therefore, necessary to enhance the high-frequency response of the video amplifier by introducing equalizing networks with suitable time constants. Sufficient equalization should be provided to give the desired square-wave response.

The decay characteristics of most standard phosphors are such as to require considerable equalization provided by networks with different time constants in several stages of the video amplifier. Their relatively long decay generally results in appreciable reduction of the useful signal-to-noise ratio.

The persistence of the P15 phosphor is comparatively so short that less equalization is needed. If used without an ultraviolet filter, less equalization is required than for other standard phosphors but a complex network is nevertheless needed because the decay characteristic is not a simple exponential curve but a curve of a complex function. When used with a filter to pass only the ultraviolet radia-

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tion, the P15 effectively has a persistence so extremely short that the small amount of equalization needed can be supplied by only one network. As a result, circuits and adjustments are simplified and substantially the same signal-to-noise ratio is obtained, in spite of filter absorption, as will the arrangement using the total radiation from the phosphor.

Resolution of better than 700 lines at the center of the reproduced picture can be produced by the 5WP15. To obtain such resolution in the horizontal direction, it is necessary to use a video amplifier having a band-width of about 10 megacycles.

Soft x-rays are produced when the 5WP15 is operated with an anode No. 2 voltage above approximately 20,000 volts. These rays can constitute a health hazard unless the tube is adequately shielded. Relatively simple shielding should prove adequate.

MULTIPLE BABY SITTING

Six children in adjoining student-veteran homes at Camp Shanks are monitored while their parents are out. Major Jean L. Wood and his wife use separate microphones, amplifiers and labeled loudspeakers for each baby channel, with a clock at each microphone to warn if any channel fails

Versatile Power Supply

BY WILLIAM B. MILLER
Standards Engineer
Bardwell & McAlister Inc.
Burbank, California

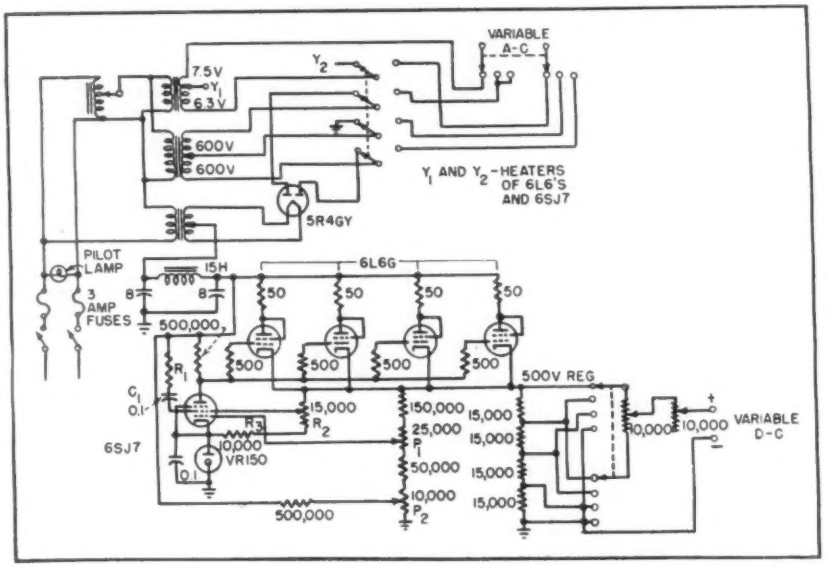
BOTH direct and alternating voltages for meter testing are provided by the circuit shown. The a-c output is continuously variable from 0 to 1,200 volts and the maximum d-c output is fixed and regulated at 500 volts. Lower d-c voltages are obtained by means of a variable voltage divider which allows smooth control down to zero volt.

Low ripple was not a factor in the design and only ordinary filtering was used. However, the action of the regulator section and a small amount of feedback resulted in a measured ripple of 0.4 millivolt. Regulation was important and is quite good. After the output was set at 500 volts, it held with no perceptible change, with a line variation from 90 to 125 volts and a load variation of from 0 to 200 milliamperes.

Four 6L6G's, triode connected, are used in parallel as the series regulators, and a 6SJ7 as the amplifier. Resistors in each plate lead of the 6L6's equalize the current distribution, and resistors in each grid lead help stabilize and limit the grid current. A total of 200 ma may be safely drawn from this combination.

The 6SJ7 control amplifier was considered as an r-f tube and care in wire placement was used to eliminate erratic operation and unwanted oscillations. Resistors R_2 and R_3 supply the screen voltage and also the keep-alive voltage for the VR150, the current through the latter being about 15 ma with no load on the supply. The divider network across the output supplies the control grid voltage for the 6SJ7 and also feeds the grid any fluctua-

(continued on p 140)



Up to 1,200 volts a-c and 500 volts d-c are available from the power supply

Now GERMANIUM VARISTORS

(CRYSTAL RECTIFIERS)

by

Western Electric

Western Electric announces a new line of Germanium Crystals! There are five types — all exceptionally compact and sturdy . . . all identical in mechanical dimensions . . . and all supplied with pigtails for soldering into circuits. Electrical characteristics have been standardized to meet the requirements of currently known applications.

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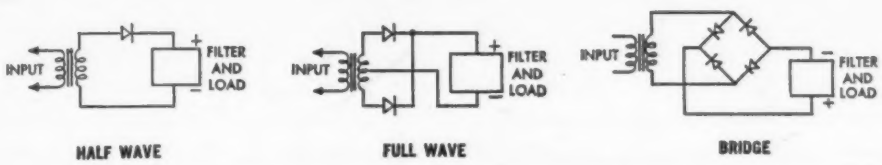
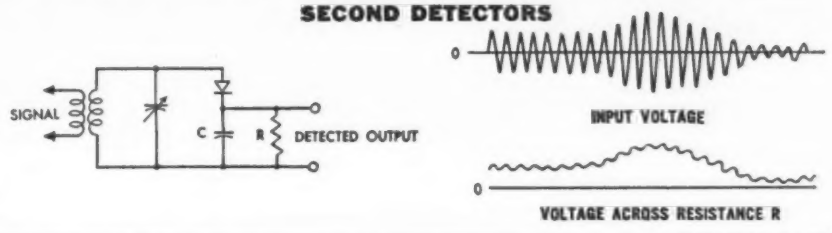
FOR THESE (and many other) APPLICATIONS

RECTIFIERS



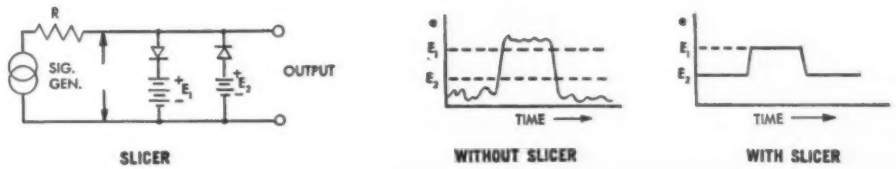
May be used as power rectifiers at peak inverse voltages up to 115, and peak forward currents up to 125 ma. By connecting matched units in series or parallel, these values may be increased.

SECOND DETECTORS



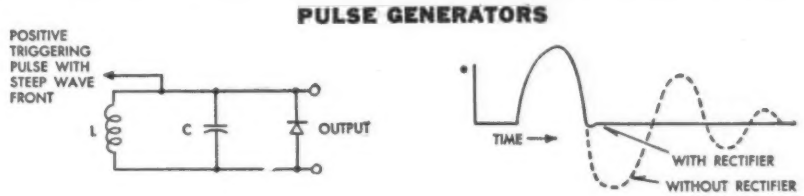
Used to good advantage as second detectors at frequencies to over 60 mc. They have much lower impedance than vacuum tube diodes, and are particularly effective in low-impedance circuits. The 1N47 is tested for operation at 100 mc.

SLICERS, LIMITERS AND CLIPPERS



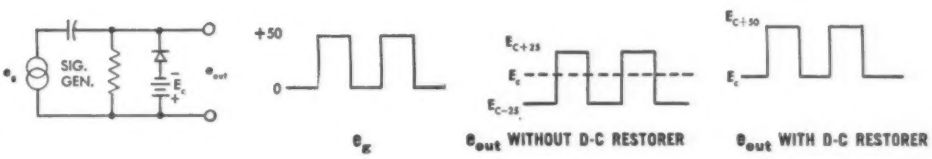
In the slicer circuit, biased units conduct current through R when critical voltages E_1 and E_2 are reached, preventing overswing. In limiters and clippers only one branch need be used, with addition of low-impedance d-c return path across output terminals or through signal generator.

PULSE GENERATORS



Unit damps out the oscillation after one-half cycle, producing a single pulse shaped similarly to half of a sine wave. This pulse may be clipped, provided clipper is isolated from pulse-producing tuned circuit to prevent damping out desired half cycle.

D-C RESTORERS



Circuit shows d-c restorer applied to a network widely used for coupling successive amplifier stages. The germanium crystal prevents output voltage from swinging below E_c; thus negative peak of wave is established at E_c.

For complete specifications and application data sheets on Western Electric Germanium Crystals, call your local Graybar Broadcast Representative, or write Graybar Electric Company, 420 Lexington Avenue, New York 17, N. Y.

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THE ELECTRON ART

Edited by FRANK ROCKETT

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Research Stimulates Electronic Applications 130
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Reproducing Handwriting 180
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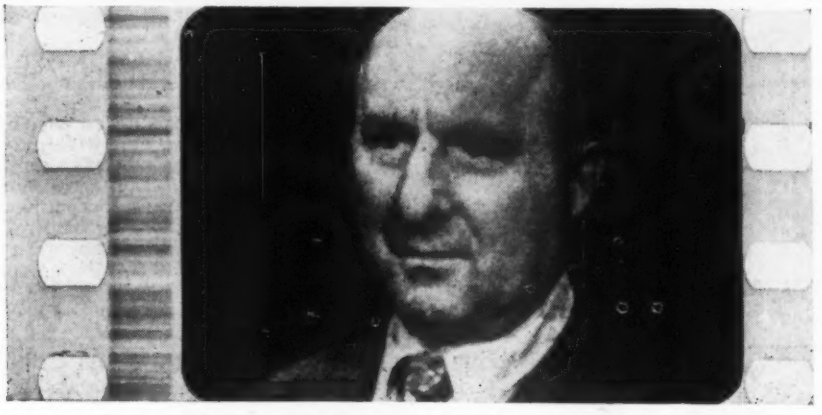
Survey of New Techniques 190

Motion Picture Television Projected from Film

EXPERIMENTAL television pictures of boxing contests were projected onto the 18 by 24 foot screen of the New York City Paramount theater as the event took place. The technique will be used to provide practically simultaneous showings in theaters of local news events. When network facilities become available it may be extended to an intercity basis, independently of television broadcasting networks. The film from which the picture is projected can be stored, edited, and reused.

Television picture is recorded on 35 mm film, which is then completely processed in 66 seconds, by the equipment that Paramount's vice-president Paul Raiborn is inspecting



Section of experimental film (not the one shown publicly) shows clarity of picture; note variable density sound track also recorded onto film from audio relayed over some uhf

The experimental equipment with which the system was demonstrated in April consisted of a DuMont image orthicon pickup camera, two pairs of 7 kmc microwave RCA relays (to transmit the signal from the Brooklyn Navy Y.M.C.A. to the Manhatten Paramount building via the N. Y. Daily News building), and terminal equipment developed by Paramount engineers. The terminal equipment reproduces the television picture at 30 frames a second and electronically blanks it to permit recording on film at 24 frames a second. The film is completely processed (developed, fixed, washed, and dried—no trouble being encountered from grain or soft geliten), and feed directly into the projector. The process can be operated so fast that a frame is projected 30 seconds after it is exposed. However, at such a rate, sludge tends to collect on the film; a 66 second processing interval has been found most satisfactory.

Because of the extreme sensitivity of the image orthicon (greater than that of film), this technique, in addition to offering quicker projection, is superior to that of using a motion picture camera to obtain news reels under adverse lighting conditions. Not only was the showing experimental in that the terminal equipment had only been completed 10 days before the showing (it was the first time the engineers had seen the picture projected onto the screen of the main theater), it was also experimental in that the audience was not apprised of the showing until it took place; they applauded at the conclusion of the 15 minute showing. The picture was as sharp as direct film news shots and had a remarkably long tonal range.

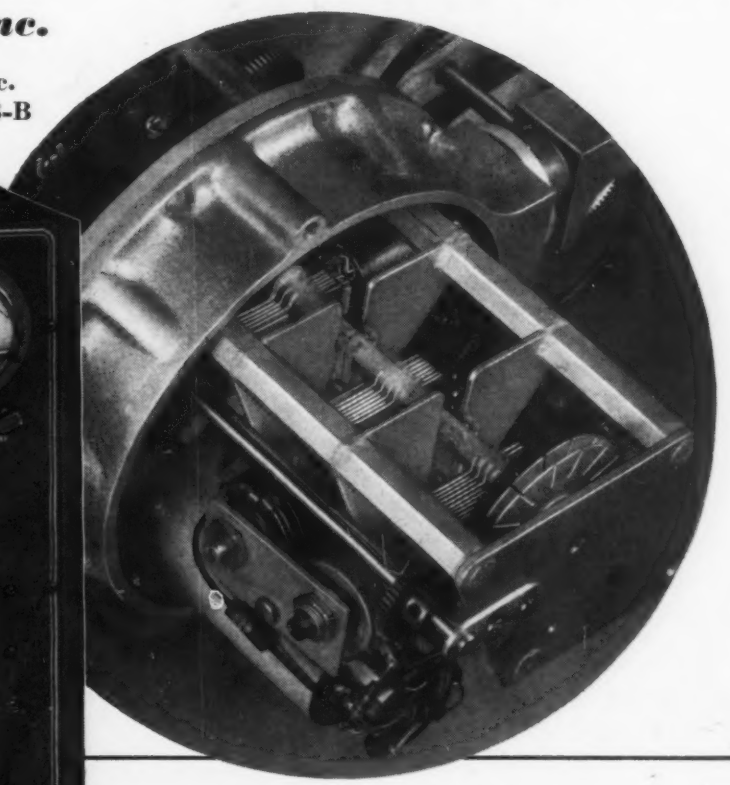
Crystal Diodes in Computers

LARGE scale digital computers using many electronic tubes dissipate a great deal of heat. To reduce the amount of heat that must be removed by the air conditioner for the computer, and to reduce the operating power and mechanical size of the computer, germanium

FM SIGNAL GENERATOR

Type 202-B 54-216 mc.

Additional coverage from 0.4—25 mc. with accessory UNIVERTER Type 203-B



Shown above is an interior view of the 202-B Signal Generator RF assembly with shield cover removed. Heavy aluminum castings form the mounting base of this RF unit resulting in a compact and highly rigid structure. Girder type condenser frame construction, multiple rotor shaft grounding contacts, and welded interstage shield plates are but a few of the many design features of this unit which give added circuit stability.

Designed to meet the exacting requirements set forth by leading FM and television engineers throughout the country, the 202-B FM Signal Generator has found widespread acceptance as *the* essential laboratory instrument for receiver development and research work.

Frequency coverage from 54 to 216 megacycles is provided in two ranges, 54 to 108 megacycles and 108 to 216 megacycles. A front panel modulation meter having two deviation scales, 0-80 kilocycles and 0-240 kilocycles, permits accurate modulation settings to be made.

Although fundamentally an FM instrument, amplitude modulation from zero to 50%, with meter calibrations at 30% and 50%, has been incorporated. This AM feature offers increased versatility and provides a means by which simultaneous frequency and amplitude modulation may be obtained through the use of an external audio oscillator.

The internal AF oscillator has eight modulation frequencies ranging from 50 cycles to 15 kilocycles, any one of which may be conveniently selected by a rotary type switch for either amplitude or frequency modulation.

The calibrated piston type attenuator has a voltage range of from 0.1 microvolt to 0.2 volt and is standardized by means of a front panel output monitor meter.

The output impedance of the instrument, at the terminals of the R.F. output cable, is 26.5 ohms.

AVAILABLE AS AN ACCESSORY

is the 203-B Univerter, a unity gain frequency converter which, in combination with the 202-B instrument, provides the additional coverage of commonly used intermediate and radio frequencies.

R.F. Range: 0.4 mc. to 25 mc.

R.F. Increment Dial: ±250 kc. in 10 kc. increments.

R.F. Output: 0.1 microvolt to 0.1 volt. Also approximately 2 volts maximum (uncalibrated).

UNIVERTER
Type 203-B

For further information write for Catalog E

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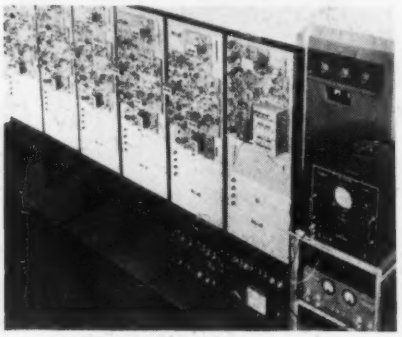
crystal diodes can be used in the switching circuits. When the potential across a diode is negative, it presents a high impedance; when the voltage is positive, it presents a low impedance. Thus the diode constitutes a convenient voltage sensitive switch. Because it consumes power from the control or switching channel, that channel should have low internal impedance. Computers using such switching networks, like that illustrated here, have large capacity but are relatively compact.



High speed computer developed at the Servomechanisms Laboratory of M.I.T. uses germanium diodes, performs arithmetical operations using five-place binary numbers, and indicates solution by neon lamps

Time Expansion of Periodic Waves

By LI-YEN CHEN
Transmission Engineer
Ministry of Communication, China

MANY METHODS have been proposed for reducing bandwidth required to transmit a certain message. Preliminary tests conducted at Polytechnic Institute of Brooklyn with a wave-expanding system show that periodic waves can be transmitted over less bandwidth than is normally required.

Signal Sampling and Expanding

A periodic wave consists of several identical cycles of a particular waveshape. To transmit this wave all that is needed is to transmit the characteristics of one cycle and knowledge of the rate at which the cycle repeats itself (waveform and frequency). Waveform can be transmitted by gating out a single cycle and elongating it in the time scale. The bandwidth required to transmit the elongated wave is reduced in proportion to the elongation. Furthermore, if the elongation has a predetermined fixed relation to the original wave, the system design incorporates knowledge of the number of cycles to be reproduced at the receiver for each transmitted cycle, and hence no additional bandwith need be used to convey this information.

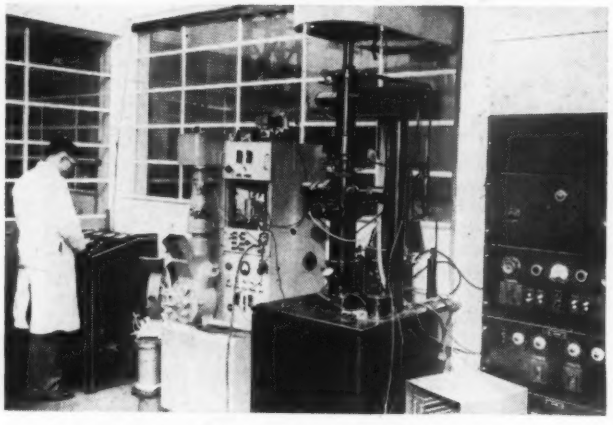
An experimental technique for expanding a wave has been developed and tested. Using a 1,000-cps frequency, the wavelength was doubled (frequency halved) and the signal transmitted as a 500-cps frequency. The wave reconstructed at the receiver of the original 1,000-cps frequency had practically the waveform of the initial signal. Whereas a technique such as recording the signal at a fast rate and playing it into the transmitter at slow speed produces a similar increase in the time scale, this sampling and expanding method produces the increased time scale without changing the elapsed duration for transmitting the complete signal.

Pulse Methods Perform Expansion

Figure 1 shows the general principle of the expander. Information

(continued on p 170)

Research Stimulates Electronic Applications in Science and Industry



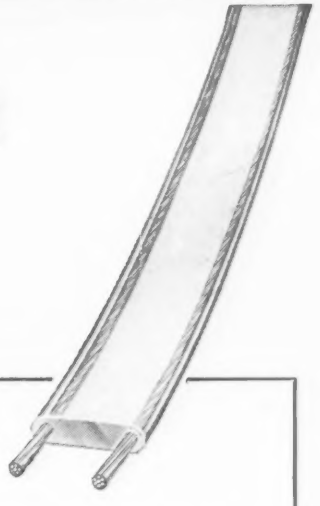
Cathode-ray oscillograph equipment is used to study transients in the high-voltage and insulation research laboratory

Scientists working on vacuum tubes such as x-ray generators for therapy; an assembled synchrotron doughnut is in foreground

Experiments leading toward physical, biological, medical, and industrial applications of electronics are being conducted at new and extensive laboratories in Staffordshire, England. Included in the equipment of the English Electric Company's Nelson Laboratories are a three million volt generator for testing transformers, a thirty million electron volt synchrotron that is being developed for the government's laboratory at Harwell, and a 140 million volt machine that is planned for cancer research. Electronic laboratories are developing television receivers, industrial controls and scientific instruments.

CONFUSING? OR AMUSING?

Lead-In Lines Play an Important Part in Television Reception



The effects of attenuation and impedance mismatch on FM and Television reception are minimized by Anaconda Type ATV* lead-in lines.

The satin-smooth polyethylene insulation of Type ATV line sheds water readily, thus avoiding subsequent impedance discontinuities. This material also has exceptionally high resistance to corrosion. Count on Anaconda to solve your high-frequency transmission problems—with anything from a new-type lead-in line to the latest development in coaxial cables. 47430

An Anaconda Trade-Mark

A Type ATV Lead-In for Every Need

Anaconda offers a complete selection of Type ATV lead-in lines for 75, 125, 150 and 300 ohms impedance unshielded and 150 ohms shielded. For an electrical and physical characteristics bulletin, write to Anaconda Wire and Cable Company, 25 Broadway, New York 4, N. Y.

ANACONDA from mine to consumer

ANACONDA WIRE AND CABLE COMPANY

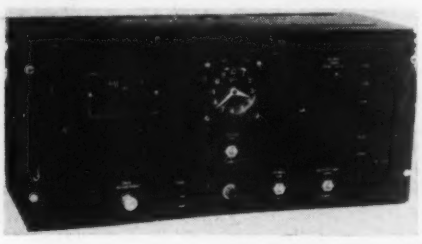
NEW PRODUCTS

Edited by A. A. McKENZIE

New equipment, components, tubes, testing apparatus and products closely allied to the electronics field. A review of catalogs, handbooks, technical bulletins and other manufacturers' literature

Frequency Standard

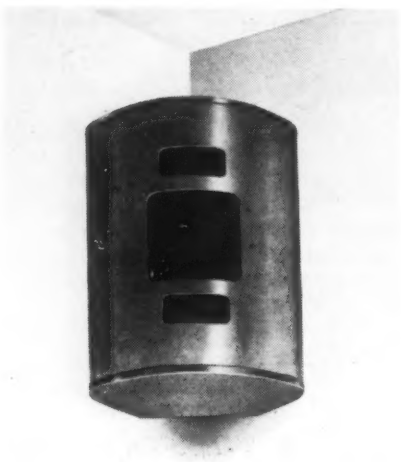
AMERICAN TIME PRODUCTS, INC., 580 Fifth Ave., New York 19, N. Y. Type 2121A frequency standard is designed to provide an accuracy of one part in 100,000. Power output is up to 110 volts, 10 watts, at 60 cycles; power input is 110 volts, 45



watts, at 50 to 400 cycles. Net weight of the unit with cabinet is 25 lb.

Wall Speaker Cabinet

JENSEN MFG. CO., Chicago 38, Ill. Two new wall mounting enclosures, model H-81 for 8-inch speakers and model J-61 for 6-inch speakers, have been announced. Pictured here is the model H-81, a bass reflex sector cabinet which may be



mounted singly, in pairs, or in clusters of four around a post to obtain wide-angle distribution of sound.

Barretter Mounts

SPERRY GYROSCOPE CO., Great Neck, N. Y. These instruments are type-N holders for sensitive barretter elements used with suitable wattmeter bridges to measure absolute

microwave power within ± 5 percent accuracy. Maximum average c-w power that can be measured directly is limited to 10 milliwatts. This range can be extended to 100 watts or higher by using a suitable directional coupler or attenuator. Four models are available.

Magnetic Tape Recorder

AMPLIFIER CORP. OF AMERICA, Magnephone Division, 398-7 Broadway, New York 13, N. Y. Model SP850 high-fidelity magnetic tape recorder is a self-contained unit consisting of tape-pulling mechanism, recording amplifier with ultrasonic

bias and erase oscillator, playback amplifier, monitor amplifier and speaker. Bias frequency range is adjustable from 30 to 80 kc with a total recording and playback distortion under 3 percent at 400 cycles.

Sideband Selector

JAMES MILLEN MFG. CO., INC., Malden, Mass. Type 92105 single sideband selector employs the McLaughlin circuit which has two crystals and four tubes. The unit provides advantages of single side-

band reception on all signals rather than only to those with suppressed carrier. The unit is readily connected to any standard communications receiver.

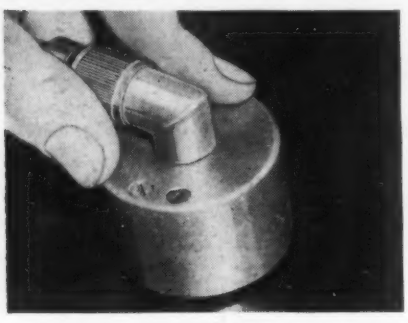
Vacuum Capacitors

DOLINKO & WILKENS, INC., 101 Hazel St., Paterson 3, N. J., has a new line of high-current vacuum

capacitors rated at 32,000 volts. The units are available in capacitances of 6, 12, 25, 50, 75, 100 and 250 micromicrofarads.

Ultrasonic Weld Tester

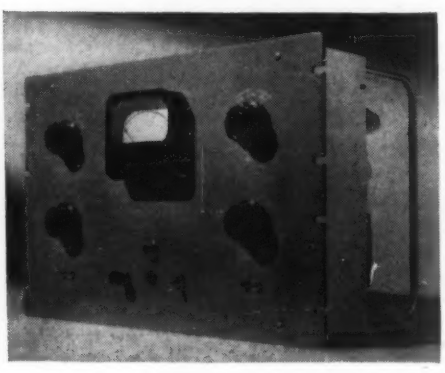
SPERRY PRODUCTS, INC., 1505 Willow Ave., Hoboken, N. J. The new angle-beam transmitter illustrated



is used with the Supersonic Reflectoscope to inspect welds. The weld itself will not constitute a reflecting interface, but any voids or inclusions will reflect a part of the energy.

Noise Suppressor

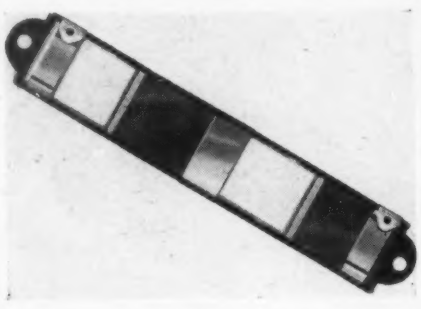
HERMAN HOSMER SCOTT, INC., 385 Putnam Ave., Cambridge, Mass. Type 910-C is the new and improved noise suppressor which functions on the exclusive dynamic-bandpass principle. Compared to previous



models, the new type features improved control circuits, extended frequency range, a continuous suppression control and more flexible remote control facilities.

Strip Selenium Rectifier

STANDARD ARCTURUS CORP., 54 Clark St., Newark 4, N. J. The Kotron strip selenium rectifiers



were designed to replace thermionic rectifiers in many circuits. Available in 75, 100 and 200-ma units they mount easily and conserve chassis space. The units can be used in combinations as full-wave rectifiers or voltage doublers.

Flying Spot C-R

RADIO CORP. OF AMERICA, Harrison, N. J. The new flying-spot cathode-ray tube, tube type 5WP15 will find use in television studios for show-

ing slides or opaque objects. It will not only produce a repetitive picture similar to that obtained with the usual monoscope, but will permit change of picture at will. It is described in an 8-page brochure.

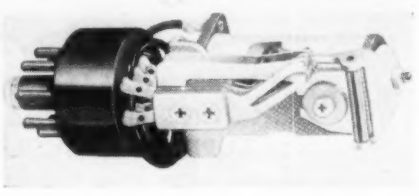
Marine Radiotelephone

GENERAL ELECTRIC CO., Syracuse, N. Y. Type MS-1-A marine radiotelephone offers four-channel operation in the marine 2 to 3-mc band,

and is completely housed in one cabinet with handset attached. The receiver delivers 2.5 watts of power to the speaker, operation being from a 6-volt battery with a current consumption of 7.5 amperes. Power output of the transmitter is 5 watts of r-f carrier.

Plug-In Relay

C. P. CLARE & CO., 4719 West Sunnyside Ave., Chicago 30, Ill. Type J small d-c relay is now avail-



able in plug-in type. Overall length of relay and octal-base plug is 3⅜ inches. Independent twin contacts and high current carrying capacity are featured.

Test Instrument

MCMURDO SILVER CO., INC., 1249 Main St., Hartford 3, Conn. The model 905A Sparx is a supersensitive aural dynamic signal tracer with an 18-watt universal output

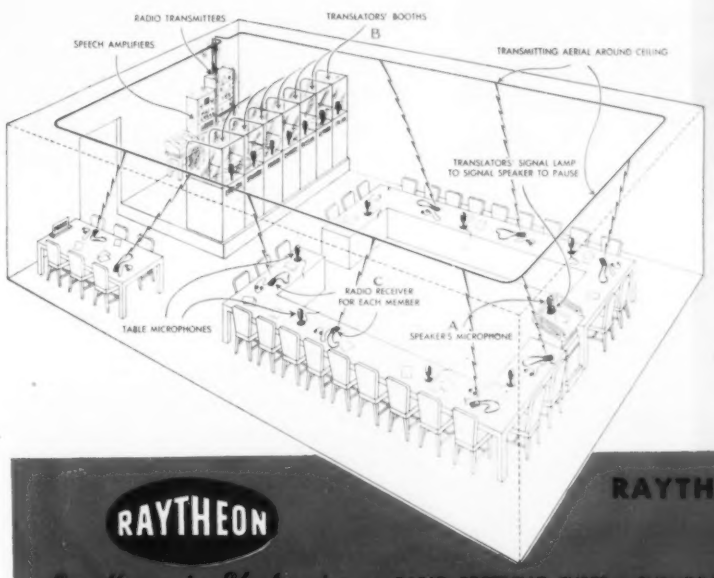
(continued on p 194)

RAYTHEON SUBMINIATURE TUBES

TRANSLATE QUALITY, DEPENDABILITY AND CONVENIENCE INTO THE PRODUCT

IBM WIRELESS TRANSLATING SYSTEM, EMBODYING FILENE-FINLAY PATENTS, EMPLOYS RAYTHEON TUBES

Here's How It's Done — The words of the speaker (A) are transmitted to interpreters (B) who are working at microphones. As each interpreter hears the speech he immediately makes the translation in his particular language. All the translations are conveyed to the listeners (C) who select, by dial, the language they wish to hear.



This is the lightweight receiving set, with aerial in the shoulder strap for complete freedom of movement while listening. It contains three RAYTHEON Subminiatures, two 2E42s and one 2E36. Two stages of radio amplification are provided, diode detector with automatic volume control, and a pentode output section connected to the headphones. The set measures $1\frac{5}{8}$ x $4\frac{1}{8}$ x $5\frac{1}{2}$ inches and weighs only $1\frac{1}{2}$ pounds. There is excellent speech tone with ample volume, sensitivity and selectivity between the channels that deliver any one up to seven languages.

Why International Business Machines Corporation and other manufacturers of high grade electronic equipment use RAYTHEON Subminiature Tubes.

1. **Reduced Product Size . . . Increased Product Salability.** Raytheon filamentary Subminiatures are flat. Batteries can be tiny because of extremely low filament drain.
2. **Plug Into Standard Sockets.** All Raytheon Subminiatures can either be soldered in or plugged into readily available sockets.
3. **Raytheon Reliability** — the result of unique methods and nine years continuous production of long-life Subminiature Tubes.
4. **Readily Available From Stock** — over half a million on tap at all times. Over 30 types. Standard throughout the world.
5. **At Your Local Distributor's** — over three hundred Raytheon Special Purpose Tube Distributors ready to serve you quickly and intelligently.

Write for Data Sheets on Raytheon Subminiature Tubes

RAYTHEON
Excellence in Electronics

RAYTHEON MANUFACTURING COMPANY
SPECIAL TUBE SECTION
Newton 58, Massachusetts

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Voice of America!...

. . . ON audiodiscs*

The Voice of America gives to other nations a full and fair picture of American life, aims and policies, plus factual news of the world and the United States.

Broadcast in twenty-three languages, these programs blanket Europe, Latin America and the Far East, with a potential radio audience of more than 150,000,000 persons.

Of the thirty-two hours of daily broadcast, approximately one-fourth of the time is devoted to news, one-half to additional comment and informational programs, and the remainder to music and entertainment.

A substantial part of these daily programs is recorded and, due to the excellent quality of these transcriptions, such recorded portions cannot be distinguished from the *live* transmissions.

Today, as from the beginning, the recorded parts of these broadcasts are on AUDIODISCS.

AUDIO DEVICES, INC., 444 Madison Avenue, New York 22, N.Y.

Export Department: Rocke International Corp., 13 E. 40th Street, New York 16, N. Y.

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they speak for themselves audiodiscs

NEWS OF THE INDUSTRY

Edited by JOHN MARKUS

IRE plans for professional groups; Audio Engineering Society launched; new microwave relay chains; 19 new books reviewed

Broadcast Operator License Proposal Amended

IN AUGUST 1947 the FCC proposed a change in rules applying to operator licenses for the broadcast service. After considering all available comments and information from interested parties the Commission recently modified its proposal as follows:

A new group of commercial operator licenses, to be known as the Broadcast Operator Group, will be established: (a) limited broadcast operator license; (b) broadcast-technician operator license; (c) broadcast-engineer operator license.

New examination elements will be added to presently existing elements 1 through 6, as follows:

(7) Practical Broadcast Operation. Provisions of law, rules and regulations governing the operation of standard and f-m broadcast stations, and procedures involved in normal operation (including minor transmitter adjustments) to insure compliance therewith.

(8) Technical Broadcast Theory and Practice. Intermediate electronics theory and practice as applied to the operation, adjustment and maintenance of standard and f-m broadcast stations, technical regulations, and standards of good engineering practice regarding the operation of all classes of broadcast stations and of the equipment permitted or required.

(9) Advanced Broadcast Theory and Practice. Advanced technical theory and practice applicable to the operation, adjustment and maintenance of a-m, f-m, television and other classes of broadcast stations and associated equipment, including special antenna systems.

Examination requirements for the licenses in the new broadcast operator group will include, in addition to satisfactory ability to understand the English language and to receive and transmit spoken messages in English, the following written examination elements:

Limited broadcast operator license—1, 2, and 7.

Broadcast technician-operator license—1, 2, 7 and 8.

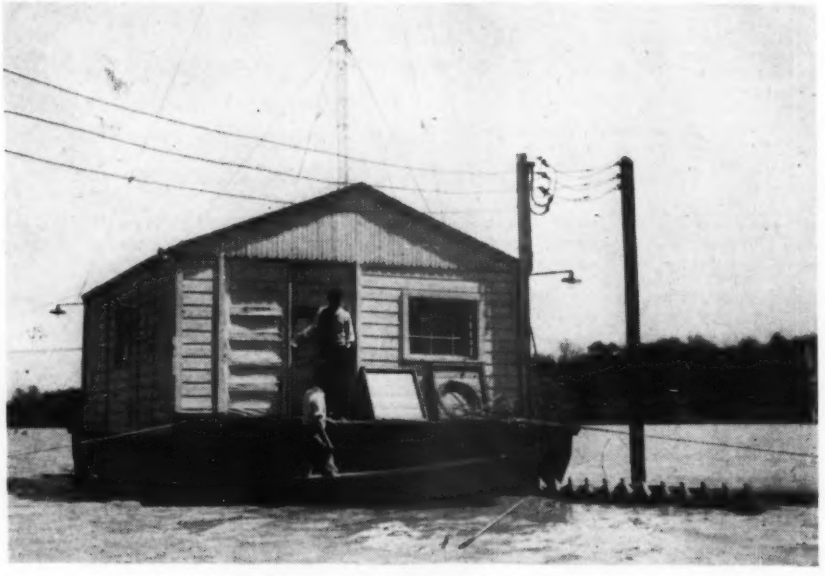
Broadcast engineer-operator license—1, 2, 7, 8 and 9.

The scope of authority of licenses of the new broadcast operator group will be substantially as follows:

Limited broadcast operator license—Holders of this class of license may operate any standard broadcast station having a maximum licensed power of not more than 1 kw and not employing a directional antenna system, or any f-m broadcast station having a maximum licensed effective radiated power of not more than 1 kw, or any remote pickup or standard broadcast station, provided (1) that one or more holders of a radiotelephone first class operator license, broadcast technician-operator license, or broadcast engineer-operator license is regularly employed on a full-time basis by that station, and (2) that holders of the limited broadcast operator license are prohibited from making any repairs or adjustments beyond the protective interlocks of the radio station transmitter, except in the presence and under the direction of a person holding one of the higher classes of licenses.

Broadcast technician-operator license—Holders of this class of license may operate any class of broadcast station, provided that (1) in the case of a standard broadcast

BROADCASTERS SOLVE FLOOD PROBLEM



Radio station WKYW, Louisville, Ky., now has a water-borne transmitter near the Ohio River. In the path of frequent floods, it was installed on a barge and rises with the river. The barge is held by steel cables

station having a maximum licensed power in excess of 1 kw or using a directional antenna system, or (2) in the case of an f-m broadcast station having a maximum licensed effective radiated power in excess of 1 kw, or (3) in the case of an international, facsimile, or television broadcast station, one or more holders of a broadcast engineer-operator license is regularly employed on a full-time basis by that station.

Broadcast engineer-operator license—Holders of this class of license may operate any class of broadcast station.

Audio Society Launched

AT a meeting April 13 in New York City attended by over 125 members, the constitution and bylaws of the Audio Engineering Society were formally adopted. C. J. Lebel, chairman of the meeting, announced that membership was already over 500 and growing steadily.

Adoption of the constitution marks the launching of a new national technical society serving the field of electronics. Provisions are made for establishment of local or regional sections when authorized by the Board of Governors of the national society.

The committee entrusted with formulation of the constitution was headed by Harry N. Reizes and composed of Isabel Capps, R. J. Stier, C. R. Sawyer, A. A. Pulley, C. G. Brodhun, D. L. Richter, C. J. McProud, C. J. Lebel, A. Cezar and J. Daniels.

Classes of membership provided for are as follows:

(1) *Honorary Members:* — A person of outstanding repute and eminence in the science of audio engineering or any of its allied arts, may be elected to honorary membership by the board of governors and thus become entitled to all the rights and privileges of the society.

(2) *Fellows:* — A member who has rendered conspicuous service, or is recognized to have made valuable contribution to the advancement in or dissemination of knowledge of audio engineering, or the promotion of its application in practice, may be elected a fellow of the society.

(3) *Members:*—Any person active in audio engineering who has an academic degree, or its equivalent in scientific or professional experience in audio engineering or in a closely related field or art, shall be eligible for election to membership in the society and upon election shall be entitled to all the

(continued on p 227)

MEETINGS

JUNE 10-12: Symposium sponsored by Armour Research Foundation and the Physics Department of the Illinois Institute of Technology, at Stevens Hotel, Chicago. Papers and planned discussion will cover instrumentation, techniques and application of electron and light microscopy.

JUNE 21-25: 51st annual meeting of the American Society for Testing Materials, at Detroit, Michigan.

JUNE 21-25: AIEE Summer General Meeting, Mexico City.

JULY 14-16: International symposium on noise, held by the Acoustics Group of the Physical Society and the Roger Institute of British Architects, at the Royal Institute, Portland Place, London, W. 1.

AUG. 20-29: All-Electrical Exposition, Pan-Pacific Auditorium, Los Angeles, Calif.

AUG. 24-27: AIEE Pacific General Meeting, Spokane, Wash.

SEPT. 4-6: ARRL Convention, Milwaukee Auditorium, Milwaukee.

SEPT. 13-17: Third Instrument Conference and Exhibit, Convention Hall, Philadelphia, Pa.

SEPT. 27-OCT. 2: Third National Plastic Exposition, Grand Central Palace, New York City.

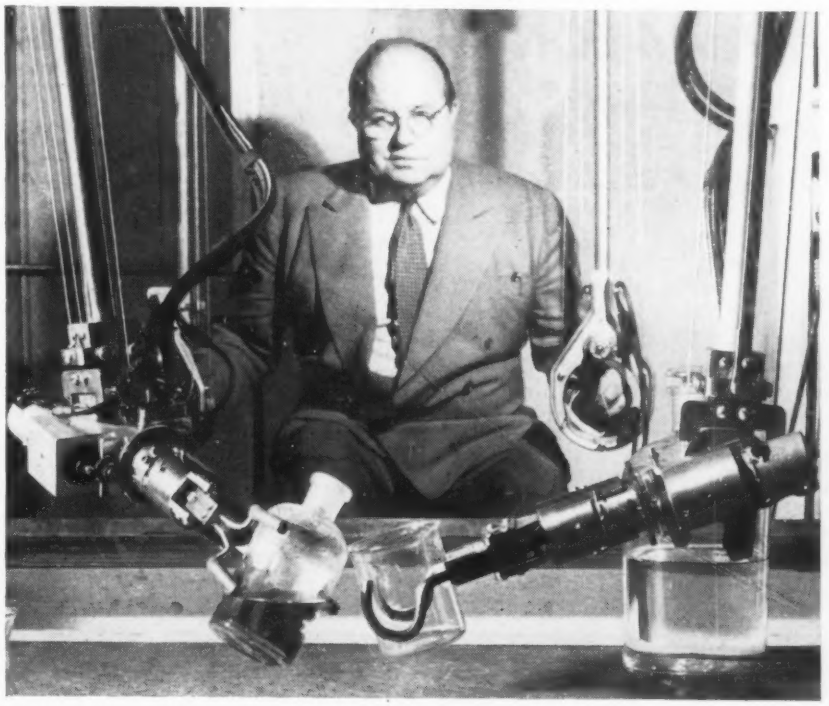
SEPT. 30-OCT. 2: Pacific Electronic Exhibition and IRE west coast Annual Convention, Biltmore Hotel, Los Angeles, Calif.

OCT. 5-7: AIEE Middle-Eastern District Meeting, Washington, D. C.

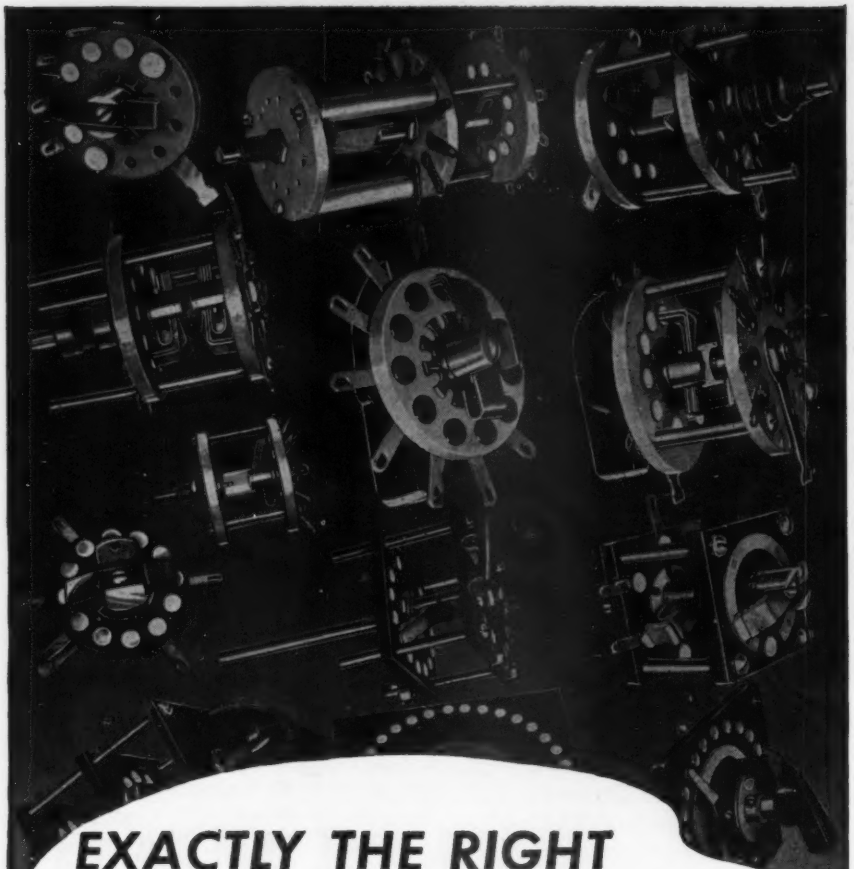
OCT. 11-12: FM Association Second Annual Convention, Sheraton Hotel, Chicago.

NOV. 4-6: National Electronics Conference, Edgewater Beach Hotel, Chicago.

MECHANICAL HANDS FOR RADIOACTIVE AREAS



A remote-control manipulator using mechanical hands can perform chemical experiments or operate machine tools in radioactive areas. In actual use the hands would extend over a protective 8-ft wall into the area while operated from an outside room. General motion of the robot corresponds to that given the handles by the remote operator but wrists, rotated electrically by the use of synchros, can be twisted around completely any number of times. The device is used at the Knolls Atomic Power Laboratory near Schenectady, N. Y., and was developed by John Payne of the Atomic Power Division of the G. E. Research Laboratory



EXACTLY THE RIGHT
SELECTOR SWITCH
FOR YOUR APPLICATION

OTHER SHALLCROSS PRODUCTS

Akra-Ohm Precision Resistors
Combined Kelvin-Wheatstone Bridges
Fault Location Bridges
Kilovoltmeters
Kilovoltmeter Multipliers
Shallcross Variaten Attenuators
Multi-Resistor Standards
Portable Power Supplies
Low Resistance Test Sets (Bond Testers) etc.

Tailoring a selector switch to a specific application *economically* is not a job for engineers who only produce a few types occasionally. Modern switch engineering calls for plenty of "know how." It calls for a background of dozens of standard types from which adaptations can be made. Not the least important, it calls for highly specialized dies, equipment and trained assemblers . . . All of which Shallcross offers in fullest measure.

WRITE FOR SPECIFICATION SHEET

Let Shallcross quote on your Selector Switch requirements. Standard types, most of them subject to broad adaptations, cover switches for bridges, decade boxes, transformer tapping, resistor and capacitor paralleling, inductance tapping, television, and many other exacting uses. Ask for Form C-1.

SHALLCROSS
MANUFACTURING COMPANY
Dept. E-68, Collingdale, Pa.

(continued from p 126)

tions in the output voltage. The amplifying action of this tube provides the regulating effect. Any change on the grid of the 6SJ7 is amplified and transmitted as bias to the 6L6's, which changes their series resistance in the proper direction to counteract the fluctuation.

By varying P_1, the output voltage is brought to the exact value desired. The divider was calculated to put the grid 5 volts above the cathode, or 155 volts; P_1 has a range of about 50 volts. Potentiometer P_2 helps in reducing ripple, as it feeds the unregulated voltage to the regulated side and any ripple will be partially cancelled due to the 180-degree phase difference between the two.

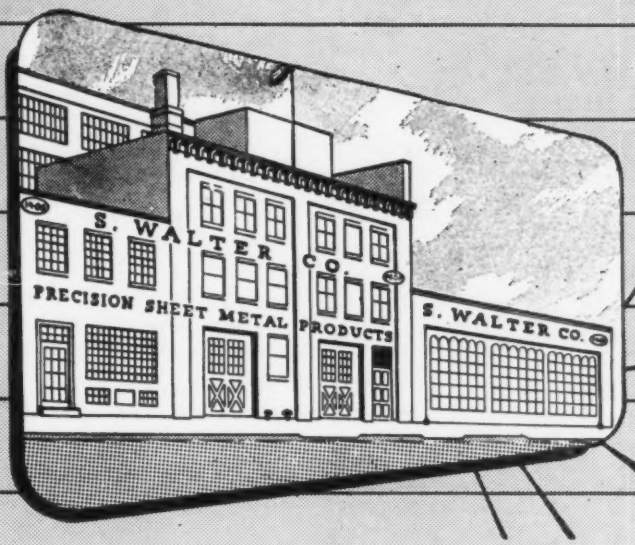
Resistor R_1 and capacitor C_1 aid considerably in ripple reduction. A 500,000-ohm potentiometer was used for R_1 and adjusted for minimum ripple voltage. If the supply is used where the load changes rapidly, a 4-μf 600-volt oil-filled capacitor across the output helps in maintaining regulation.

A-C Output

The change from d-c to a-c is accomplished by means of a 4-pole double-throw relay. When the relay is energized, it disconnects the high-voltage windings from the rectifier tube and makes them available by means of a switch. The Variac, connected to the primaries of one filament transformer and the plate transformer, controls the a-c output. When the switch selects the filament transformer, a-c from 0 to 7.5 volts is available at the terminals. With half of the plate winding switched in, up to 600 volts may be had. With the full winding, 1,200 volts are available; each range being continuously variable. The Variac is turned down whenever a change is made to prevent arcing at the relay contacts.

The resistance network across the output divides the 500 volts d-c into four ranges, each range being approximately a 125-volt step, depending on the current being drawn. Thus for the first range the voltage is 0 to 125, the second from 125 to 250, the third from 250 to 375 and the last from 375 to the full 500. The arrangement of the

AT YOUR SERVICE WITH OUR NEW FACTORY TO HELP YOU WITH YOUR SHEET METAL FABRICATION REQUIREMENTS.



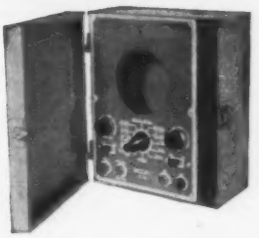
Sheet Metal Products – such as:

INSTRUMENT PANELS, RADIO COMMUNICATION CASES and ENCLOSURES, OSCILLATOR BOXES, CHASSIS and CABINET ASSEMBLIES, RACKS and SPARE PARTS BOXES, WATERPROOF CABINETS and BOXES, METAL STAMPINGS, FORMING and WELDING of FERROUS and NON-FERROUS METALS.

Thousands of varied Production Dies and Tools available at no extra charge—to speed production and reduce your costs. We specialize in "Whistler Die Setups" for economic and speedy production.

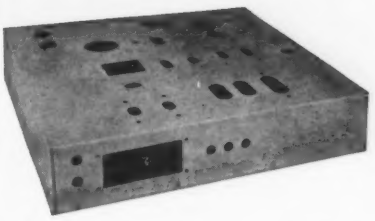
Our modern Finishing Dept. includes—Pickling — Degreasing — Bonderizing and Baked Enamel Painting of all types; thus assuring you of a fine quality product.

We can assure you of excellent workmanship and prompt deliveries. Send us your blueprints and specifications. We shall quote you immediately.

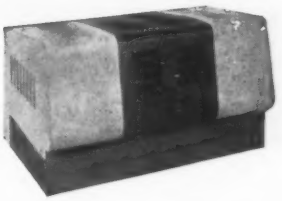


INSTRUMENT CASES

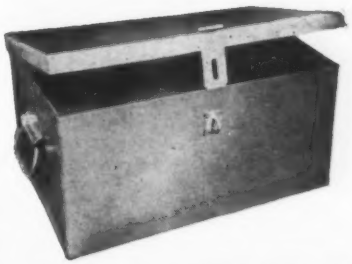
MARINE RADIO



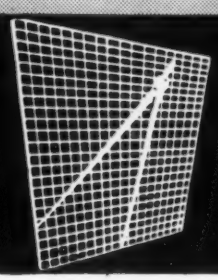
TELEVISION CHASSIS



AMPLIFIER CASES



SPARE PARTS BOXES



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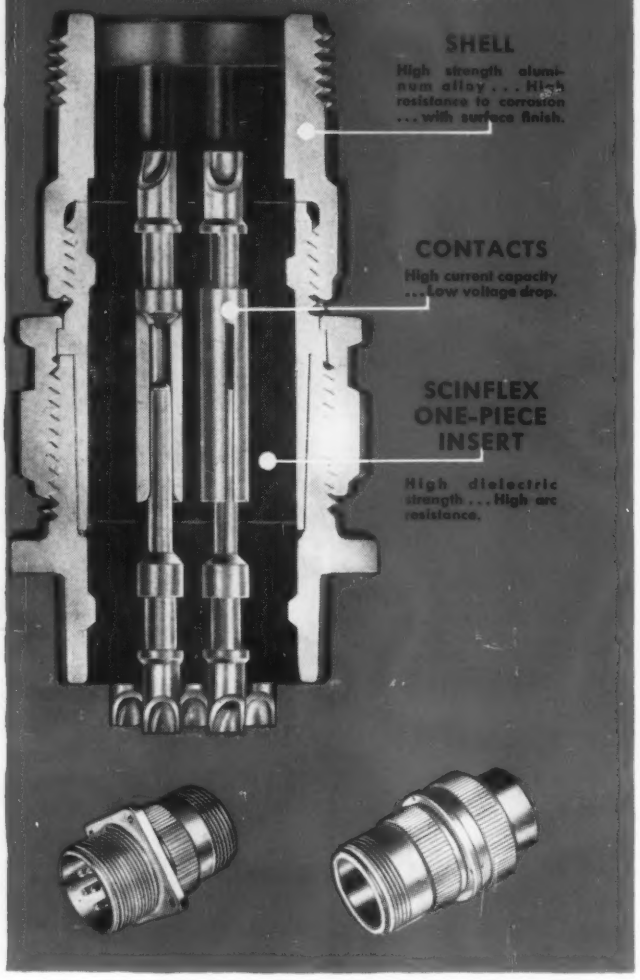
the finest ELECTRICAL CONNECTORS money can build or buy!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Phase Meter

By E. O. VANDEVEN
General Electric Co.
Schenectady, New York

THE PHASE METER is a device that measures the phase angles of a low or high frequency polyphase voltage supply. Essentially this is accomplished by developing on the screen of a cathode-ray oscilloscope a circular sweep at the polyphase supply frequency. Each phase voltage of the polyphase supply is then separately amplified, clipped, differentiated and again amplified.

In the output of each phase amplifier are pulses which are established in time by their respective phase voltage. These pulses are mixed and applied to the Z-axis amplifier of the oscilloscope to intensity modulate the circular trace, causing a dark or bright spot to appear for each phase voltage. The angular displacement between the spots is then a measure of the angular displacement between corresponding phase voltages. The phase angles can be read by calibrating the oscilloscope screen radially in degrees.

A block diagram of the phase meter is shown in Fig. 1. One phase

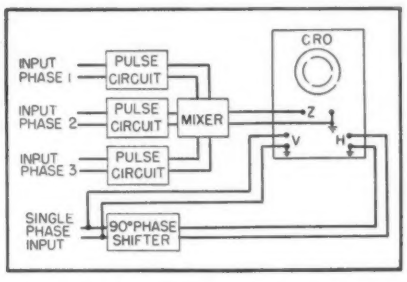

FIG. 1—Block diagram of phase detector

of the three-phase supply is applied to a device which shifts the phase by 90 degrees. This is done, since to obtain a circular sweep it is necessary to apply to the horizontal and vertical amplifiers voltages of the same frequency but separated in phase by 90 degrees. The pulse forming and mixing circuits are also indicated.

The phase meter was developed

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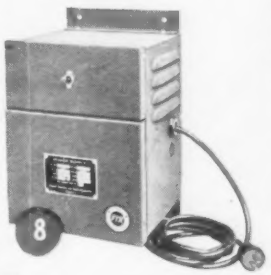

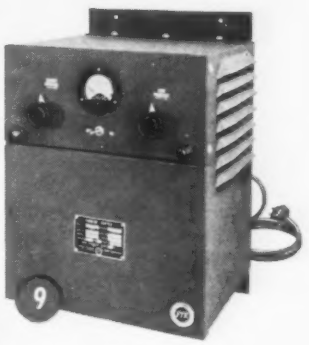

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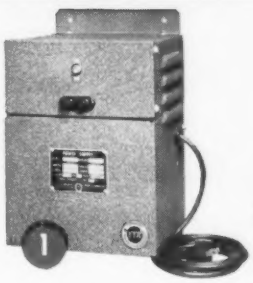

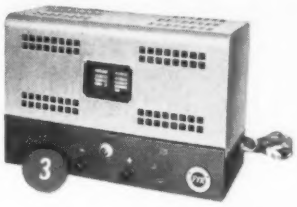

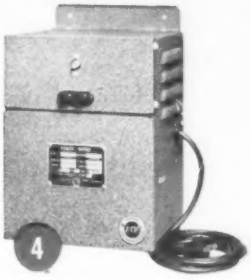

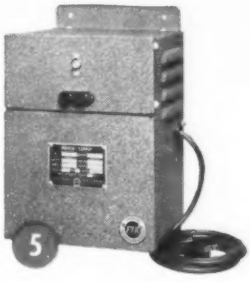

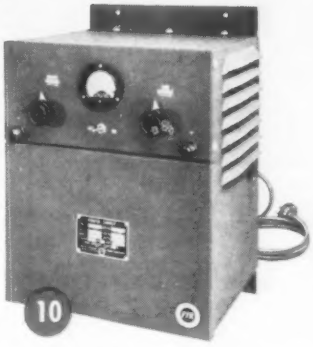

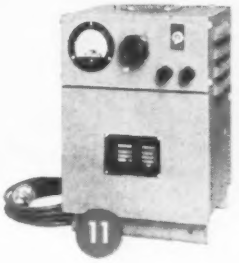

RATINGS

FILTERED						UNFILTERED					
	A-C Input		D-C Output				A-C Input		D-C Output		
Code Number	Volts	Phase	Cycles	Volts	Amps.	Code Number	Volts	Phase	Cycles	Volts	Amps.
1 FTR 3093-AS	115	1	60	12	3	6 FTR 3300-DS	115	1	60	2-32	50
2 FTR 3128-BS*	115	1	60	22-30	10	7 FTR 1342-AS	115	1	50/60	6	4
3 FTR 3246-BS	115	1	60	6	10	8 FTR 3341-AS	115	1	50/60	28	5
4 FTR 3138-BS	115	1	60	12	5	9 FTR 3339-BS	115/230	1	50/60	6-24	18
5 FTR 3185-AS	115	1	60	12	7.5	10 FTR 3340-BS	115	1	50/60	5-70	12
*Filtered and regulated						11 FTR 3352-BS	115	1	50/60	5/10	20/10

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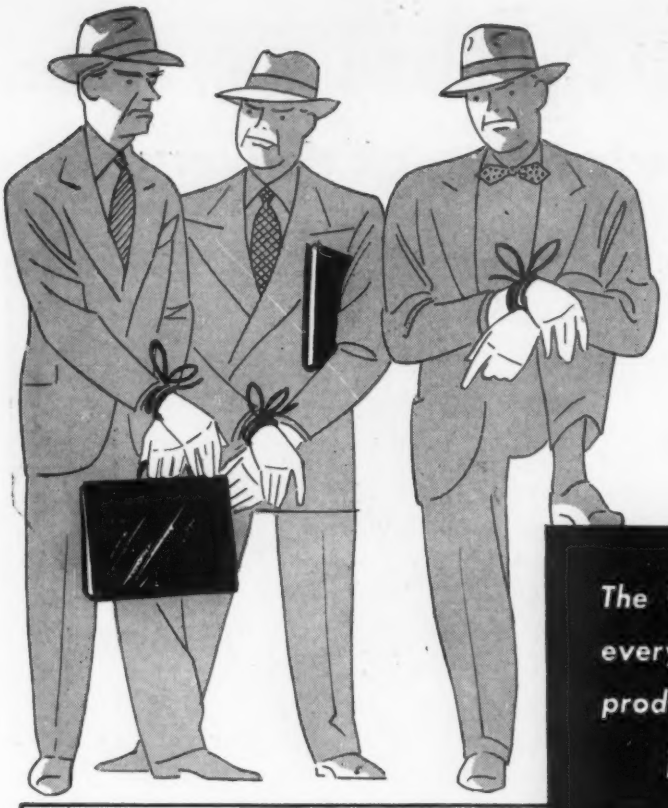

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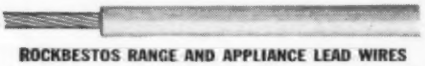

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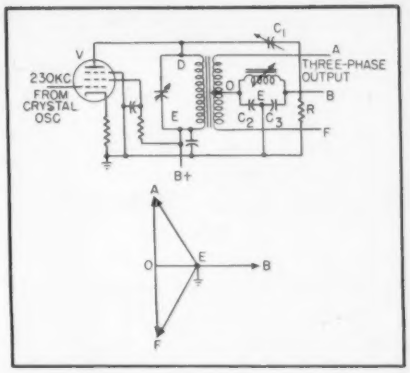

FIG. 2—Single-phase to three-phase transformation circuit and phase diagram

for work with the 2H21 phasitron tube, used to generate crystal-controlled f-m. The phasitron has three-phase r-f applied to the deflector electrodes. A crystal oscillator at approximately 230 kilocycles is the signal source. This single-phase voltage is transformed to three-phase by employing a modified Scott transformer connection.

The single- to three-phase transformation circuit, with the associated phase relationships, is shown in Fig. 2. Amplifier tube *V* supplies a transformer load, the secondary of which is center tapped. Secondary voltage, *AF*, is shown vectorially on the phase diagram. The *OB* vector, displaced 90 degrees from *AF*, is obtained by shifting the phase of the primary voltage *DE* by 90 degrees. Since *DE* and *AF* are in phase, vector *OB* is then 90 degrees from *AF*.

Resistor *R* is essentially connected from *B* to *E* which is part of a tuned circuit. Therefore by detuning the tuned circuit slightly from the resonant point the reactance from *B* to *E* can be made to appear inductive. This inductive reactance is in series with C_1, and by proper adjustment of these two parameters the voltage *BE* will be displaced from the supply voltage *DE* by 90 degrees. By properly establishing the ratio of C_2 to C_3, the point *E* is selected along the *OB* vector. Point *E* is grounded providing a neutral point for the balanced three-phase system.

For the phasitron to operate with minimum distortion it is necessary that the exciter supply phase voltages of equal magnitude and angular displacement. The phase meter was developed to facilitate the ad-

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justment of the exciter supply for perfect three-phase output.

Circular Sweep

Figure 3 shows the circuit used to obtain circular sweep. The single-phase, 230-kc signal feeds a pentode amplifier. The amplifier plate circuit has a tuned transformer which, when resonated, gives a 90-degree phase shift between primary and secondary. Proper adjustment of the secondary tuning

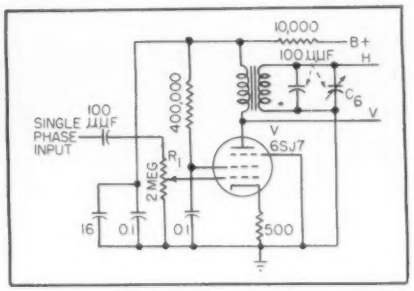

FIG. 3—Circuit of circular sweep generator

capacitor is accomplished by observing the pattern on the c-r tube. When this capacitor, and the horizontal and vertical gains, are correctly set, the result will be a circular trace on the cro screen.

The pentode amplifier is run class A and with an unbypassed cathode resistor. This is to minimize distortion of the voltages applied to the vertical and horizontal amplifiers. The cro amplifiers must also have low distortion, or it will be impossible to obtain perfect circular sweep. Circle size is controlled by R_1.

One of the pulse-forming circuits is shown in Fig. 4. Phase voltage is applied to V_{1A}, a cathode follower. This tube transforms from high-impedance input to low-impedance output across L_1.

Operation

Accuracy of the meter depends more than anything else on the coupling circuit between V_{1A} and V_2, and the operation of V_2. The voltage developed across L_1 is at least 30 volts rms. Therefore the grid of V_2 swings from minus 50 volts to 50 volts plus, less the drop across R_3C_3. The tube begins to conduct when the input voltage rises to approximately −4.5 volts. When it

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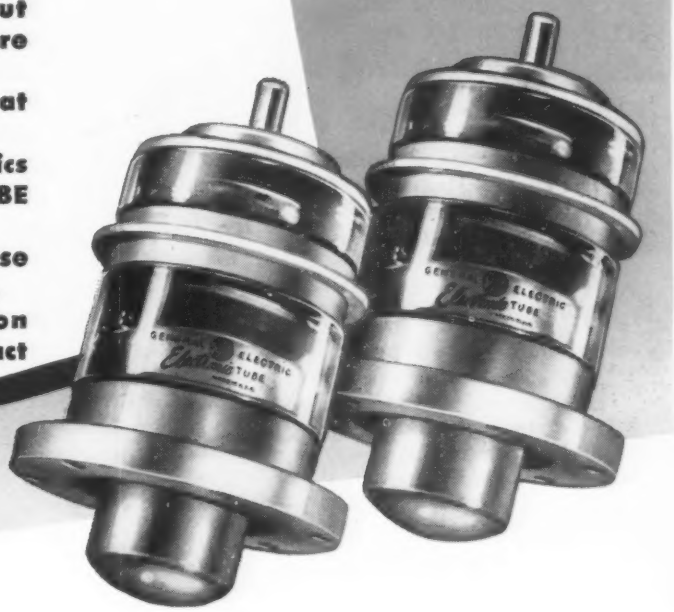

RATINGS

Filament voltage	6.3 v
Filament current	240 amp
Grid-plate transconductance	11,000 micromhos
Interelectrode capacitances:	
Grid-filament	24 micromicrofarads
Grid-plate	15.7 micromicrofarads
Plate-filament	0.5 micromicrofarads
Type of cooling	water and forced air
Plate ratings per tube, Class B r-f power amplifier (video service, synchronizing peak conditions):	
Max voltage	5,000 v
Max current	2 amp
Max input	10 kw
Max dissipation	5 kw
* Useful power output, typical operation (at 4,000 v and 1.7 amp, band width 5 mc)	3.4 kw
Plate ratings per tube, Class C r-f power amplifier (key-down conditions without modulation):	
Max voltage	6,500 v
Max current	2 amp
Max input	12 kw
Max dissipation	5 kw
* Useful power output, typical operation (at 6,000 v and 1.3 amp)	6.4 kw

*Includes power transferred from driver to output of grounded-grid amplifier.

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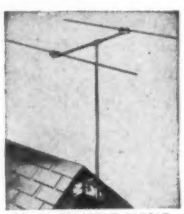

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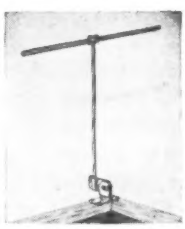

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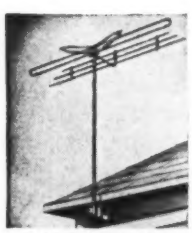

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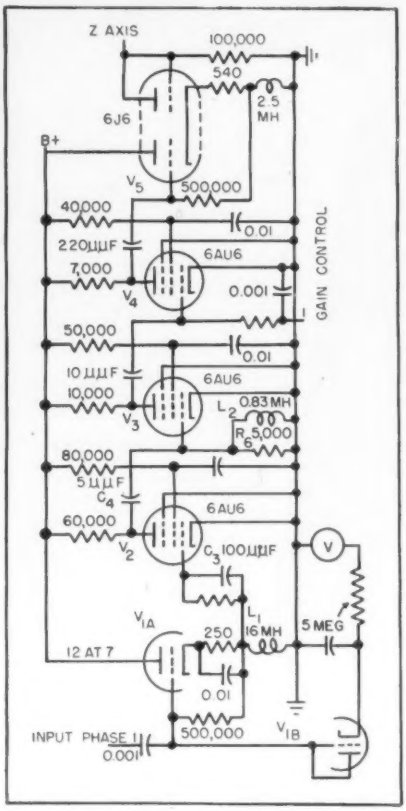

FIG. 4—Pulse generator for one phase

reaches zero volts, grid current begins to flow, resulting in a voltage drop across the grid resistor.

The output of V_2 therefore is a pulse whose leading edge is very steep. It is important that this leading edge be definitely established in time with respect to the phase input voltage.

Tube V_2 is directly coupled to L_1, since a blocking capacitor would have a discharge time constant which would develop grid bias on V_2 and change its operating point with respect to the phase input voltage. Filter R_3C_3 has a time constant which is short compared to the period of one cycle. Thus, as the voltage across L_1 rises from its peak negative value, V_2 should begin to conduct at a point determined entirely by its cutoff potential.

If the magnitude of the phase voltage is varied, this point will shift slightly, which is part of the inherent error of the device. If all phase voltages are varied by the same amount however, no net error should result. All operating points will have shifted by the same amount and in the same direction.

C_1 and R_4L_2 constitute a differentiating circuit, the voltage on V_3

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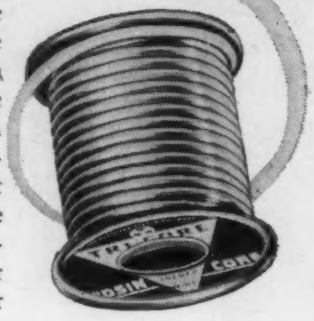

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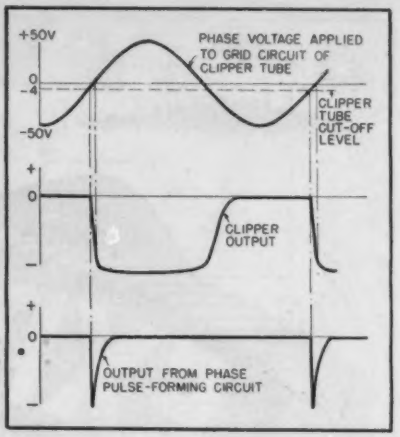


FIG. 5—Phase relations in pulse-forming circuit

grid consisting of narrow positive and negative pulses. Since V_3 is zero biased, its grid presents low impedance to the positive pulses and high impedance to the negative ones. In the output, positive pulses predominate.

Tube V_4 is an amplifier-inverter, biased beyond cutoff. The pulses are also narrowed in this stage. Output of V_4 is applied to V_5, a cathode follower. The negative pulses developed across the cathode-follower load impedance cannot be fed to the Z axis input directly. If this were done the cathode-follower loads of all phase circuits would essentially be in parallel. When one cathode follower were pulsing the remaining two would present excessive loading. The result would be insufficient pulse output voltage.

Circuit Isolation

Therefore the second section of V_5, is diode connected. Under these circuit conditions, the cathode load impedances of the inoperative cathode followers are isolated from the load impedance of the one that is operating.

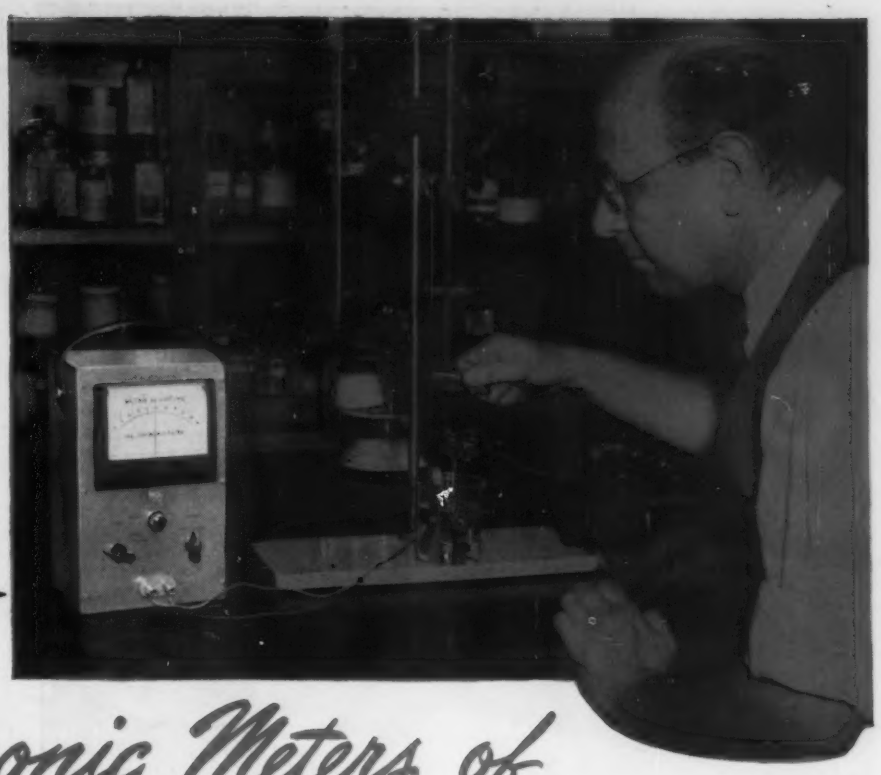
Tube V_{1B} is diode-connected to form part of a peak-reading voltmeter circuit. The meter is calibrated to read rms phase voltage.

Figure 5 shows the phase relationship between the sine wave input to the phase circuit and the output pulses appearing at the Z-axis input to the cro. The leading edge of each pulse is determined by the cutoff point of the first clipper tube in the corresponding phase circuit.

Other possible uses of the phase

THE RCA WV-84A ULTRA-SENSITIVE DC MICROAMMETER is a battery-operated vacuum-tube instrument capable of measuring currents from 0.001 to 1000 microamperes. The instrument has six ranges and can read currents in either direction by a simple switching operation. Accuracy is ± 5% of full-scale reading in the 0.01 range, ± 4% on all other ranges.

In addition to its usefulness in measuring small currents, the RCA WV-84A may also be employed as an extremely high-resistance voltmeter by the addition of external multipliers, or it may be used for the measurement of very high resistance values.



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THE RCA WV-75A HIGH-FREQUENCY VOLTOHMYST employs a push-pull dc vacuum-tube voltmeter circuit that provides excellent linearity and stability. It will measure dc resistances up to 1000 megohms, ac and dc voltages up to 1000 volts. A newly developed diode probe and internal circuit permits readings of both positive and negative peak voltages at frequencies up to 250 Mc.

In addition, the RCA WV-75A possesses all the outstanding characteristics of its well-known predecessor, Type 195-A.

←Using the RCA WV-75A High-Frequency VoltOhmyst for television receiver measurements.

THE RCA WV-73A AUDIO VOLTMETER is a sensitive high-impedance VTVM capable of readings from 0.001 to 1000 ac volts over a range of 20 to 20,000 cycles. Logarithmic scale and overlapping attenuator assure accuracy even when pointer is at either end of scale.

The WV-73A, in combination with a modulated high-frequency generator and rectifying probe, is especially useful in determining characteristics of coaxial cables and slotted lines. Standing-wave ratios can be read in terms of voltage or db ratio, since the meter is equipped with both scales.

Using Audio Voltmeter with rectifying probe to detect standing waves in wave guide.

For complete details, see your RCA Laboratory Measuring Equipment Distributor, or write RCA, Commercial Engineering, Section FY40, Harrison, New Jersey.

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meter principle include the measurement of phase shift through amplifier circuits.

R-F Heating for Cabinets

By Charles Dusenbury
Engineering and Service Department
Westinghouse Electric Corp.
Atlanta, Georgia

When Gavan Woodcrafter Inc. began the manufacture of radio cabinets, a method was needed that would eliminate human error in gluing, holding and setting. In addition they were limited in time and floor space. The solution was found in radio-frequency heating.

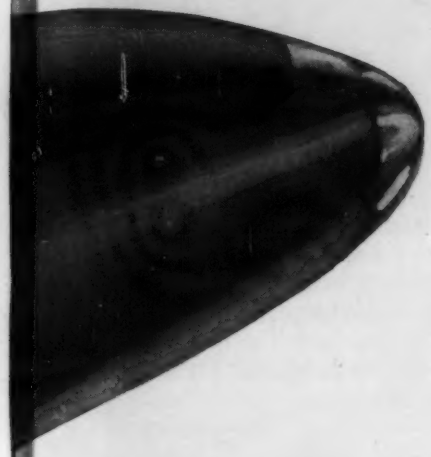
The production line cabinet fabrication set up contains five Westinghous generators, one 5 kw, 5-mc set, two 5 kw, 15-mc sets, and two 2 kw, 15-mc sets. Three of these units are equipped with two position switches to permit one jig to be heated while the other is loaded. The other two units are connected directly to the presses. The jigs and presses are constructed of plastic-impregnated wood and cost has been quite low.

With radio-frequency glue line heating and setting, cabinet construction does not rely on nails, cleats, or hand clamps to hold the cabinet together for a long glue-setting period. The various parts are coated with glue, placed in the jig and held for a few seconds during the r-f heating cycle, which sets the glue sufficiently so that they can be removed immediately for finishing. This gives a product without nails, and thus a finer finished cabinet.

The entire process consists of six steps: five gluing and heating operations and the final assembly. In forming the curved front section of the cabinet, two plys of birch or

In this jig, small blocks for the sides of the cabinet are glued and placed in slots having electrodes on each side so that r-f current passes through the glue line

000,000.
Aviation by 1952



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Descriptive Bulletin No. 10 Available

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY, U.S.A.

Two plys of birch or poplar and one of mahogany are glued together to form the cabinet front. A 5-kw, 5-mc Westinghouse generator is used

poplar and one ply of mahogany are used to form a three-ply section. The middle ply is painted with glue and the section placed in the press. Approximately 200 lb per square inch pressure is applied to the ply section and the 5-kw, 5-mc generator is then applied for a period of 120 seconds.

After the heating cycle, the panel is split into quadrants to form four cabinet front panels. One man applies glue, operates the press, and splits the panels and turns out 100 sections or 400 front panels in an eight-hour day. Production can be increased in the future by the addition of a glue spreader.

Inside Gluing

After the front panels are cut by an automatic saw, stiffening or loudspeaker boards and six small blocks are glued to the inside. This is done by a 2-kw, 15-mc generator. This unit can be used for a second heating operation while the loading is going on. The second operation is the gluing of two small blocks and a strip on the record changer mounting board. These operations respectively require 30 and 20 seconds heating time and 20 to 30 seconds loading time. The generator is adjusted so that no change is necessary when changing jigs.

The next operation is the gluing of five blocks to each side of the cabinet. Glue is applied and the blocks placed in various slots which have electrodes on each side so that the r-f current passes through

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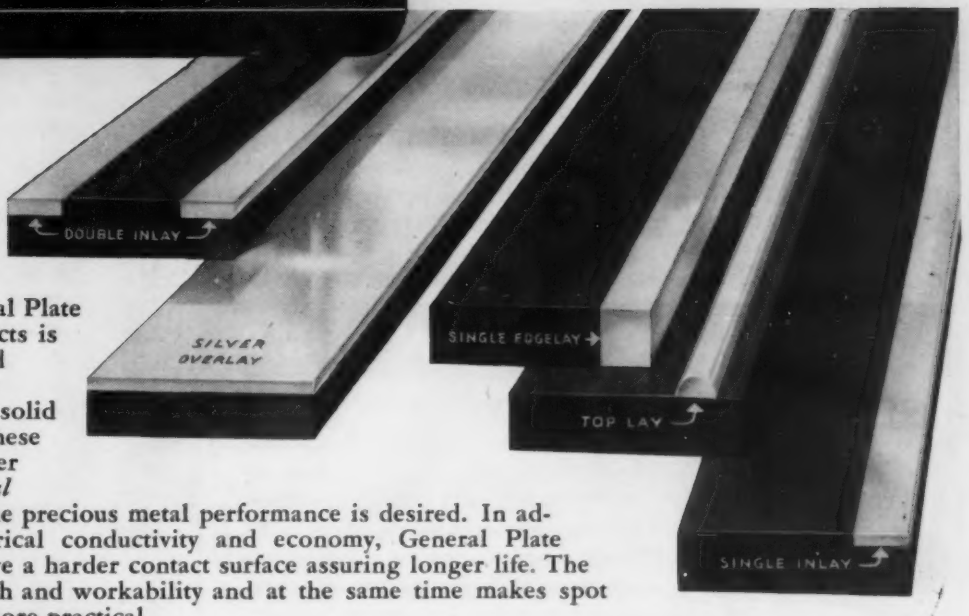

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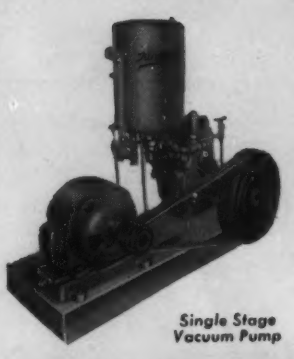

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A loudspeaker mount board and several small blocks are glued simultaneously in about 30 seconds with this jig

the glue line. When the blocks are in position, they are pushed under a press lowered by an air cylinder that applies pressure to the blocks during the heating cycle. A 5-kw, 15-mc generator with a time cycle of about 20 seconds completes the operation.

The fifth operation is heating the glue lines of the radio cabinet top. The two curved side pieces and the triangular strengthening pieces plus the front and back pieces are glued on in this case to form a top which is free from nails and is always square. The heating cycle for this operation with a 2-kw generator is about 45 seconds and the loading cycle is about the same.

Transfer Switch

The plant is laid out so that the parts flow from one operation to the next and eventually end up at the final assembly jigs. Dual presses are used for the final assembly, a transfer switch being mounted on top of the 5-kw, 15-mc generator. Two cabinets are heated at the same time in about 110 seconds. During this heating time the operators are loading the second two jigs and as soon as the first heating cycle is completed the power is transferred to the second set of jigs so that the generator is utilized about 90 percent of the time.

The cabinet must be kept square

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with pressure applied from side to side and from front to back. Two cams plus an aircraft clamp are used to accomplish this. Two operators or loaders and two assistants who apply the glue and assemble the cabinets can reach the desired production rate, slightly over 350 cabinets each day.

Since these jigs are made of heavy material with two sides and the bottom square, the resulting cabinets must be square. This eliminates one of the greatest difficulties of handmade cabinets where a complete jig is not available. An improved method of applying glue has been devised for small parts using a small rubber

Phonoradio cabinet glued together with r-f heating is free of nails and always square

bulb type syringe with a small plastic nozzle. With this, glue can be applied without excess that might cause arcing and lost time in cleanup.

Advantages

When animal glue and nails are used the cabinets must be stacked for a period of probably twenty-four hours before sanding and finishing can be accomplished. This, of course, requires floor space and additional handling, eliminating the possibilities of a production line type of assembly. Furthermore, it requires a considerable outlay for clamps, and the possibility of nails alone not holding the cabinet tight enough during the

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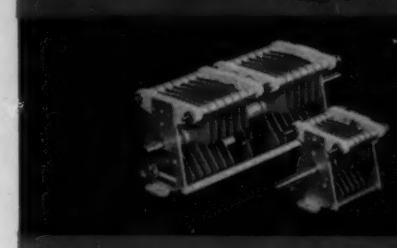
TYPE C & D — Sturdily constructed to give trouble-free operation under the most severe service, JOHNSON Type C and D Condensers cost less than any other quality condensers. Features include sturdy construction, heavy aluminum plates .051" thick, Steatite insulation and center rotor contacts on all dual models. Both front and rear shaft extensions permit ganging.
Available in 52 different models, single or dual sections, with spacing varying from .175" to .500" and maximum capacities from 50 to 1,000 mmfd.



TYPE E & F — Rugged and compact, JOHNSON Type E and F Condensers for medium and low power transmitters have more capacity per cubic inch and occupy less panel space for their rating than any other condenser on the market. Features include Steatite insulation, stator mounted above to reduce capacity to ground, front and rear shaft extensions that permit ganging.
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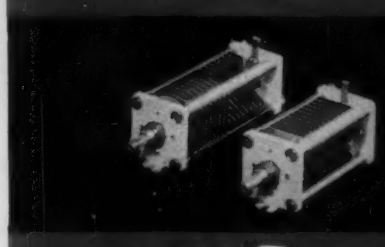
TYPE G — The JOHNSON Type G Condenser is widely used as a neutralizing condenser for medium and low power stages. It's equally famous for its outstanding performance in grid and plate tuning at high and ultra high frequencies. Features include front and rear shaft extensions and universal mounting bracket and locking nut.
Available only in single sections with single end plate. Seven models from which to choose. Capacities from 3.5 to 52 mmfd. Plate spacing from .045" to .225".



TYPE H — Combining minimum weight with small size, JOHNSON Type H Condensers are designed especially to withstand heavy vibration. Steatite end plates prevent any possibility of "short circuit loops" and permit panel mounting with both rotor and stator insulated from ground. Aluminum plates are .020" thick. End plates are 1½" square.
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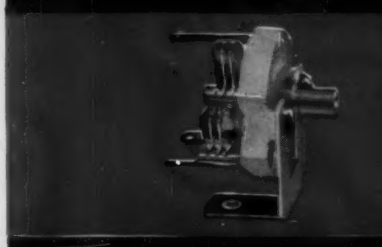

TYPE J — A midget condenser with big condenser characteristics, Type J has wider spacing than most small types, yet occupies little more space. It is ideal for oscillator and low power stages. Universal type mounting brackets make possible a variety of mountings including chassis, panel or inside tube socket type inductors. Steatite end plate.
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TYPE N — When space is limited, yet you need extremely high voltage rating, fine adjustment with uniform voltage breakdown rating throughout the full capacity range, the JOHNSON Type N Neutralizing Condenser is the perfect answer.
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TYPE 650-A IMPEDANCE BRIDGE.....$240.00

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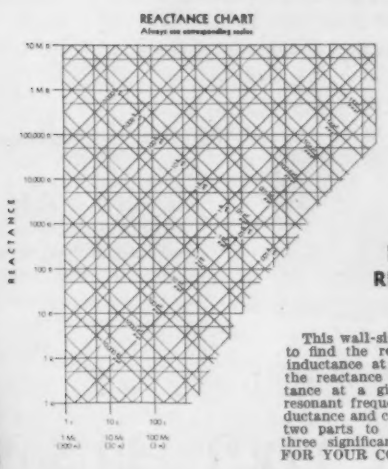

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This wall-size chart is designed to find the reactance of a given inductance at a given frequency; the reactance of a given capacitance at a given frequency; the resonant frequency of a given inductance and capacitance. It is in two parts to be read to two or three significant figures. WRITE FOR YOUR COPY.

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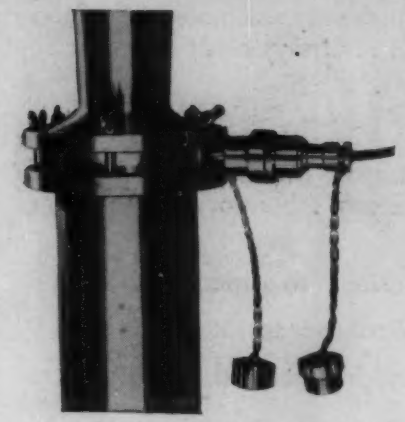

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The new C-47 edition, latest general condensed catalog, covers the thirteen major type series, specialties and certain miscellaneous items. Prices are listed on most lines with the exception of the "AN," "K," "DPD" and "DPB." Address Dept. F-120 for a copy.

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Various parts of the cabinet are assembled into one unit in two minutes at this station served by a 5-kw, 5-mc generator

glue setting period is always present.

The production line layout with radio-frequency heating saves handling and consequently gives a better product at lower cost. The fact that a man cannot apply a great deal of pressure when nailing a cabinet, unless it is in a jig, means that the parts have to be much more accurate when hand assembly and nails are used. However, the final assembly is arranged so that it draws up the material and takes up a great deal of misalignment which could only be tolerated under these conditions. Therefore, the labor required in the cutting operations need not be quite as highly skilled, nor the machines as accurate.

Carrier Shift Check Meter

BY J. W. WHITEHEAD
Central High School
Leeds, Yorkshire, England

DURING the second World War a requirement arose for a simple and convenient means of checking the setting up of a transmitter working on a carrier-shift teleprinter circuit. Continuous indication of shift was not required. The method adopted is to set a stable oscillator to the transmitter *space* frequency. The beat frequency obtained between this oscillator and the transmitter when on its *mark* frequency is then equal to the carrier shift, and by comparing the note thus produced with that generated by a stable audio frequency oscillator set to the required frequency, an

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10 ma. filament current at 1.25 volts
1.5 to 1.1 filament voltage
10^{-13} amperes grid current
25,000 ohms plate resistance
65 micro mhos transconductance

VX-21 DIODE
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1.5 to 1.1 filament voltage
3,000 volts inverse peak
10^{14} ohms insulation resistance
600 microampere emission

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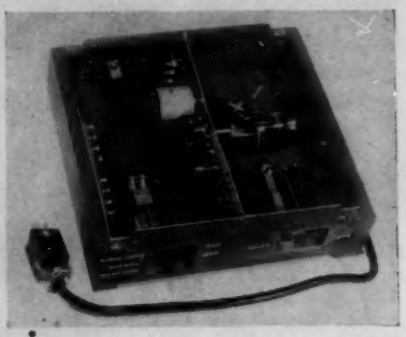


Constructed in this fashion, the carrier shift check meter fits under a BC-221 frequency meter

indication of the error in the transmitter shift tuning is obtained and can be corrected.

The circuit layout is shown schematically in Fig. 1. It contains three main items—a stable r-f oscillator, a stable a-f oscillator, and the comparison unit or mixer.

A useful, but not essential, source of r-f is an oscillating wavemeter which is provided with a crystal check, such as the U. S. Army frequency meter type BC-221. By using this meter as a basis of the scheme, it is possible to provide, at the same time, a convenient check on the transmitter carrier frequency.

For the a-f generator, a cathode-tap oscillator was found to be a convenient form, using as a resonant circuit a fixed capacitor and one winding of a transformer. Output is taken from a second winding on the transformer and fed to the mixer unit. An attempt made to carry out the final adjustment by means of d-c through a third winding was unsuccessful, and units are individually tuned by strapping further capacitors across the tuned winding.

The output from the audio oscil-

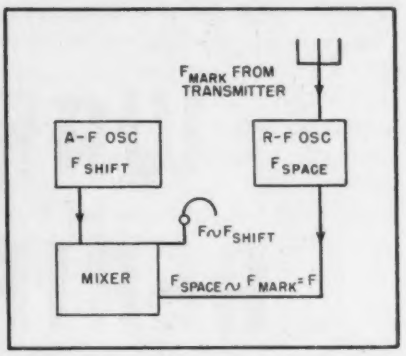
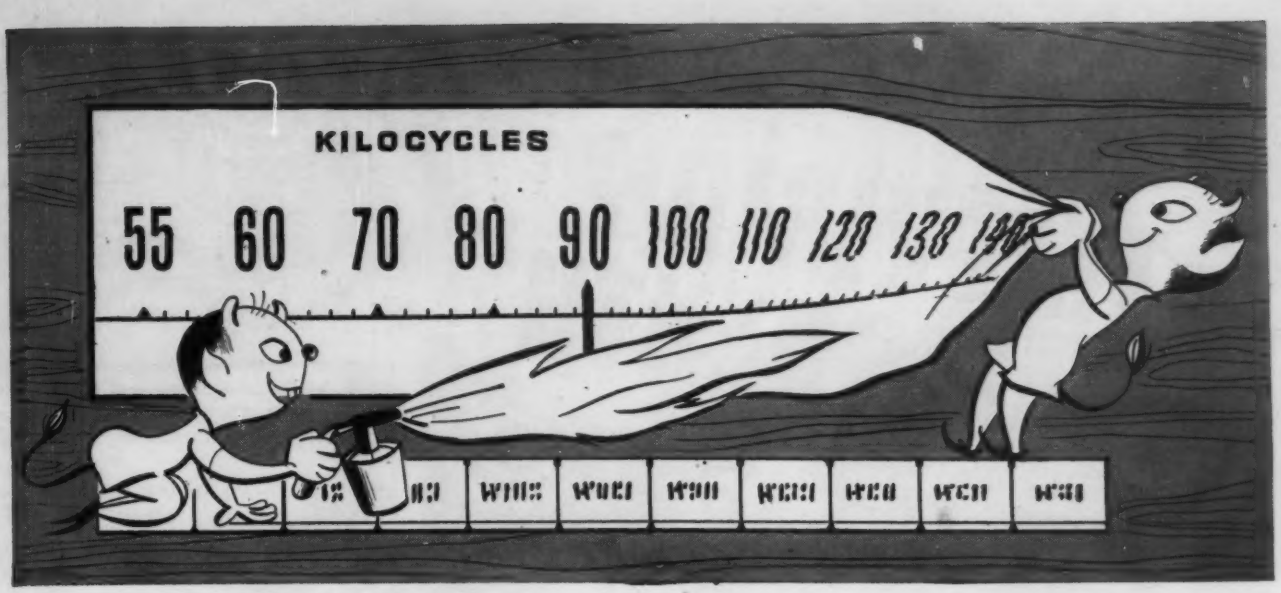


FIG. 1—Essential stages of a system for checking carrier shift



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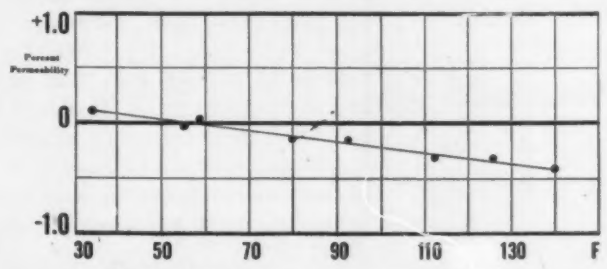

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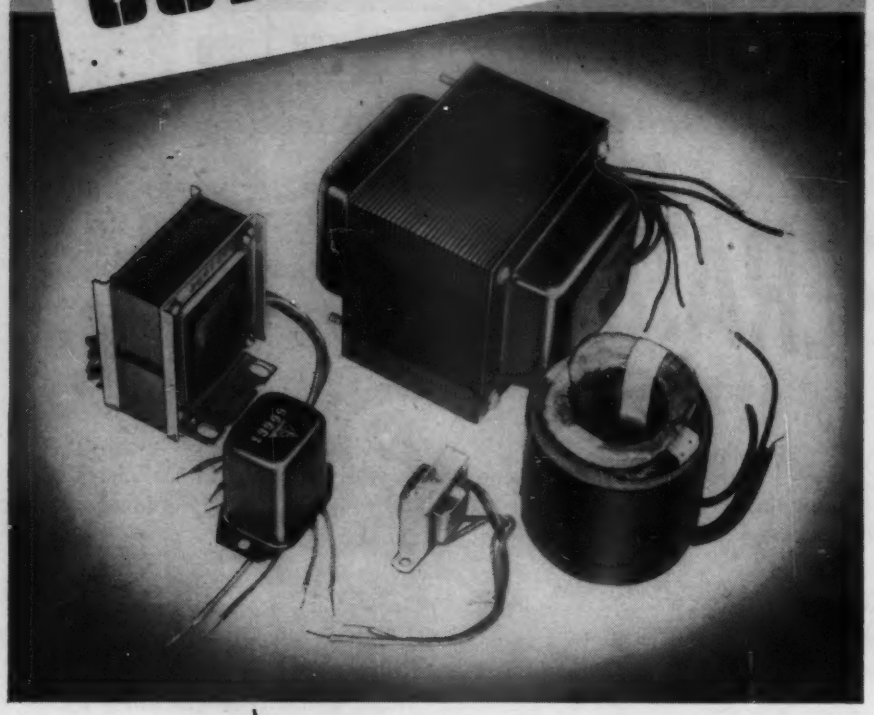

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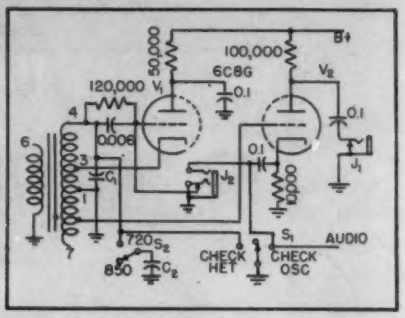


FIG. 2—Audio oscillator and mixer circuit. The center position of switch S_1 is the normal position

lator is taken to the grid-filament circuit of the mixer tube, the cathode circuit of which is fed with the audio output from the oscillating frequency meter. This latter tone is generated by heterodyne action within the meter between the *space* frequency produced by the meter and the carrier shift transmitter on its *mark* frequency. The audio signal resulting in the plate circuit of the mixer is applied to phones, and the beats heard allow accurate setting of the transmitter *mark* frequency.

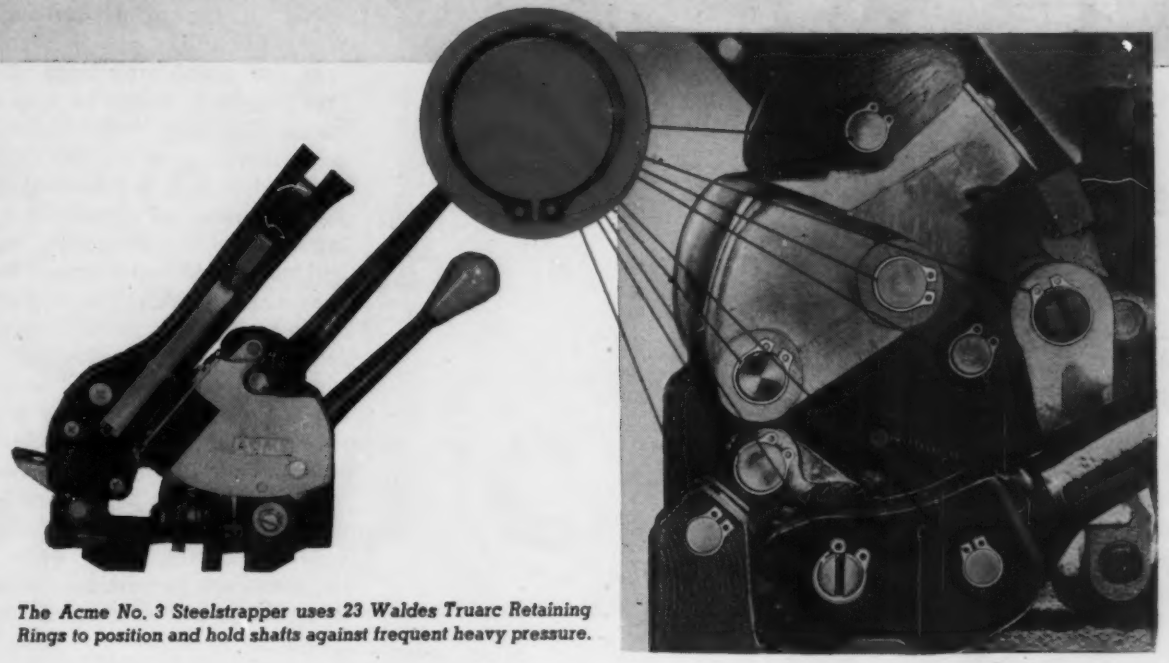
Mixer

For simplicity of construction it was considered desirable to use one tube for the two necessary circuits, and the double triode 6C8G was selected. Each section of this tube has its separate cathode, a fact which allows virtually complete isolation of the two circuits, thus making for enhanced frequency stability of the oscillator.

Referring to Fig. 2, the winding of transformer between terminal 4 and earth is tuned by means of fixed capacitors at C_1, strapped across it to produce the desired frequency. The precise values of these capacitors varies from unit to unit, and each must therefore be individually tuned. The scope of the instrument may be increased by providing switch S_2 to bring in further capacitors C_2 in parallel with the first bank to secure a second audio frequency. (The two frequencies in use were 850 and 720 cps respectively). Terminal 3 on T_1 is a tap on the tuned winding taken directly to the cathode of V_1, and terminal 4 connects with the grid of this tube via a parallel r-c combination.

Output from the a-f oscillator is

23 Truarc rings permit changeover to centerless grinding savings



The Acme No. 3 Steelstrapper uses 23 Waldes Truarc Retaining Rings to position and hold shafts against frequent heavy pressure.

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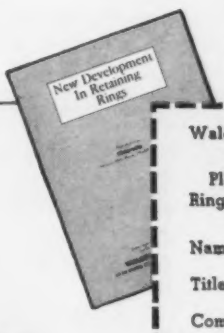

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here is a bird..

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HE is in that shell and eventually he is going to hatch out, grow up and be a bird. What kind, we don't know, because we don't know anything about his papa and mamma.

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taken from T_1 and applied to the other section of the 6C8G, V_2. The audio output from the frequency meter is applied across the cathode resistor via the capacitance. Across the plate load, therefore, appears the beat note resulting from the superposition of the two audio frequencies, and it is reproduced in the phones which are plugged in at J_1.

It was found convenient to tune the frequency meter to zero beat on *space* without switching off the a-f oscillator, and for this purpose a second jack J_2 is provided. This jack is connected across the audio input from the frequency meter, and has an additional contact which is arranged to short the grid of the audio oscillator to ground when the jack is in use, thus stopping that tube from oscillating and avoiding the complication of having a continuous additional note in the phones while tuning to zero beat.

It may be possible for an inexperienced operator to obtain an apparent tuning point when the two tones are harmonically related. A three-position nonlocking key is therefore provided to enable the two tones to be heard independently, thus ensuring that they are of exactly the same frequency.

The original prototype was calibrated against a standard tone generator to an accuracy of ± 1 cycle, and this was used as a standard against which further models were checked. During a long period of use the stability of all the models has been good and the results have been eminently satisfactory.

The particular model illustrated in the photographs was designed to fit beneath frequency meters of the U. S. Army type BC-221. This accounts for its somewhat unusual shape.

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Model VH-200

The model illustrated (VH-200) operates on one Crystal Controlled frequency (plus one closely spaced frequency) anywhere in the range 118-132 Mcs. or 132-165 Mcs., A-2 (with accessory unit) or A-3 AM. Nominal carrier power 200 watts up to 132 Mcs., reduced power up to 165 Mcs. Low temperature operation using gas filled rectifiers. Normal temperature operation using mercury vapor rectifiers. Relative humidity up to 95%. Model VH-50 has similar characteristics except nominal carrier power is 50 watts. Complete technical data on both models on request. *Aerocom* builds other radiotelegraph and telephone transmitters with accessories, and invites your inquiry if you have a communications problem.

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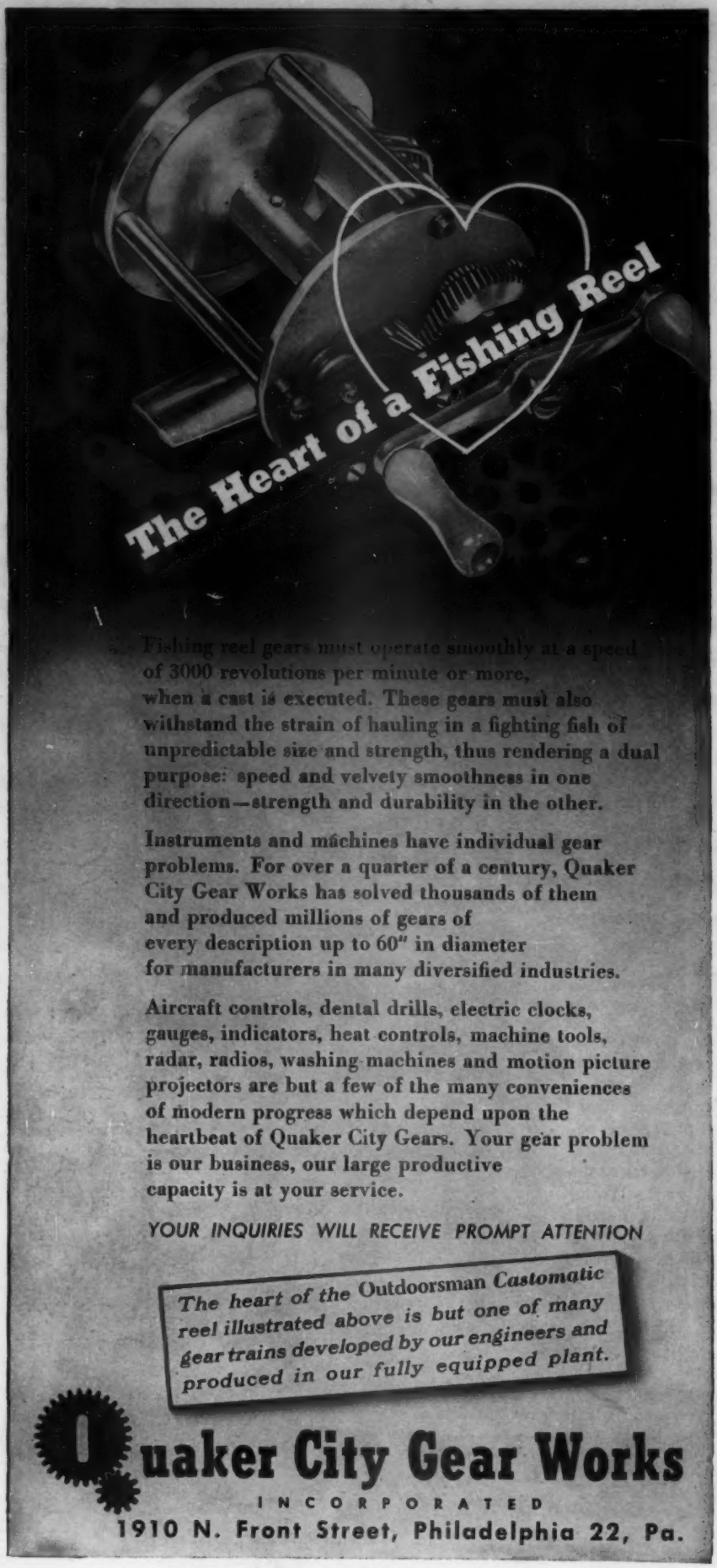

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(continued from p 130)

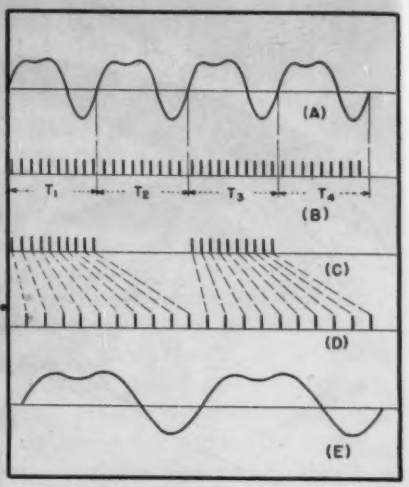

FIG. 1—Basic wave-expanding technique

of the waveshape of the input periodic wave (A) is stored in the modulated pulses (B). Because of the periodicity of the wave, the pulses in group T_1 are identical to those in group T_2. Only one group need be transmitted without reducing the information that will be conveyed (to a receiver adjusted to the system). Alternate pulse groups are therefore omitted (C) and the remaining pulses rearranged to occupy the entire time scale (D). Demodulation of these rearranged pulses gives the elongated wave (E). The bandwidth occupied by this wave (E) is half that occupied by the original one (A).

The system, comprising an arrangement of relatively common circuits, that accomplishes this novel result is shown in Fig. 2. Pulse position modulation is used to store information of the incoming wave. The repetition rate of the pulses is 10,000-cps so the system is capable of faithfully transmitting frequencies up to 3,500-cps.

A square wave of half the frequency of the input wave is obtained by a divider. This square wave gates the pulse-selecting circuit for passing pulses of alternate cycles of the signal wave, giving an intermediate signal of the general form shown in Fig. 1C.

A number of delay circuits are used to convert the pulses to the expanded time scale. The first delay circuit delays its pulse for 150 microseconds, the second circuit delays its pulse for 250 microsec-

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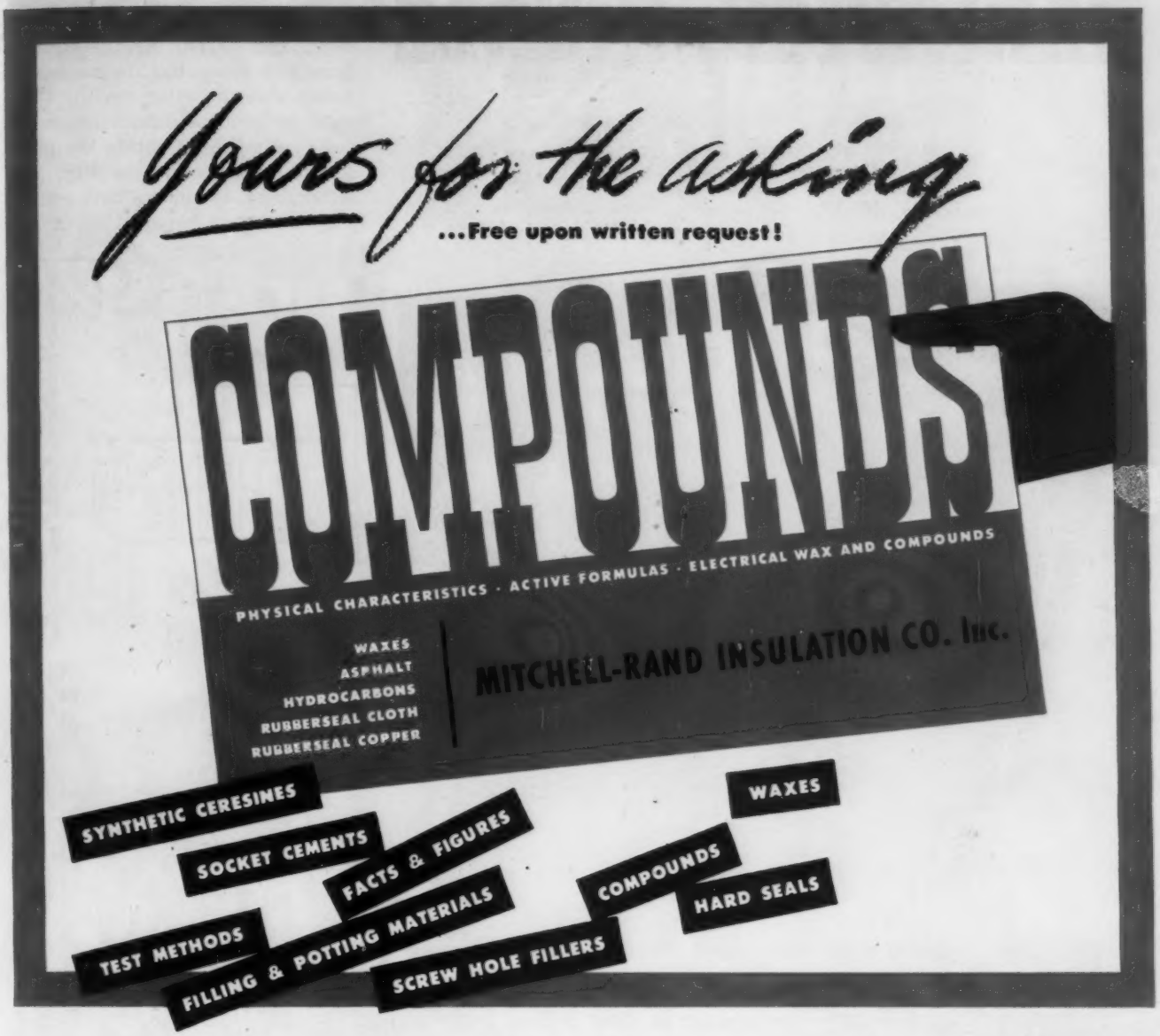

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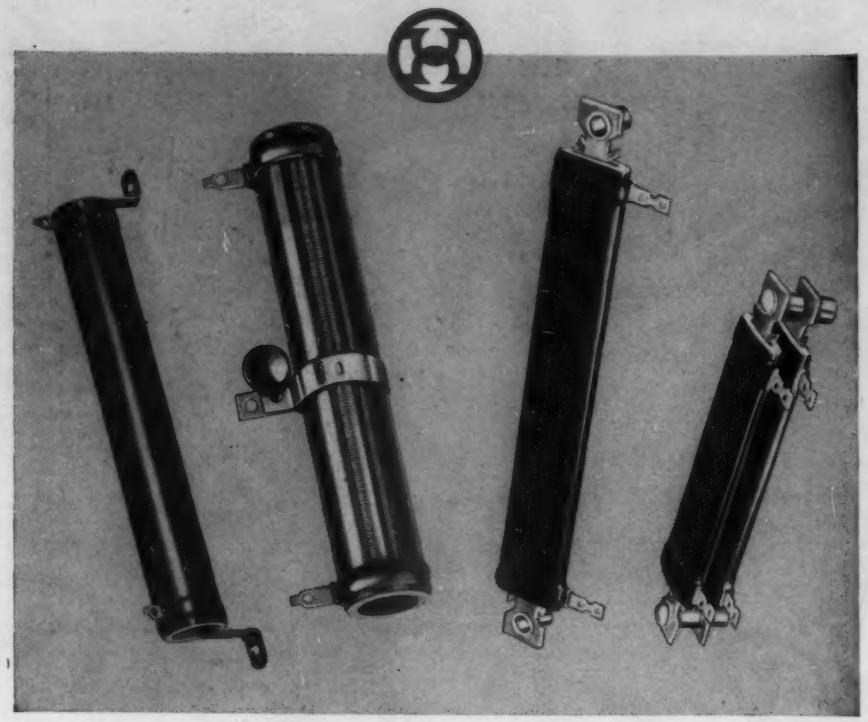

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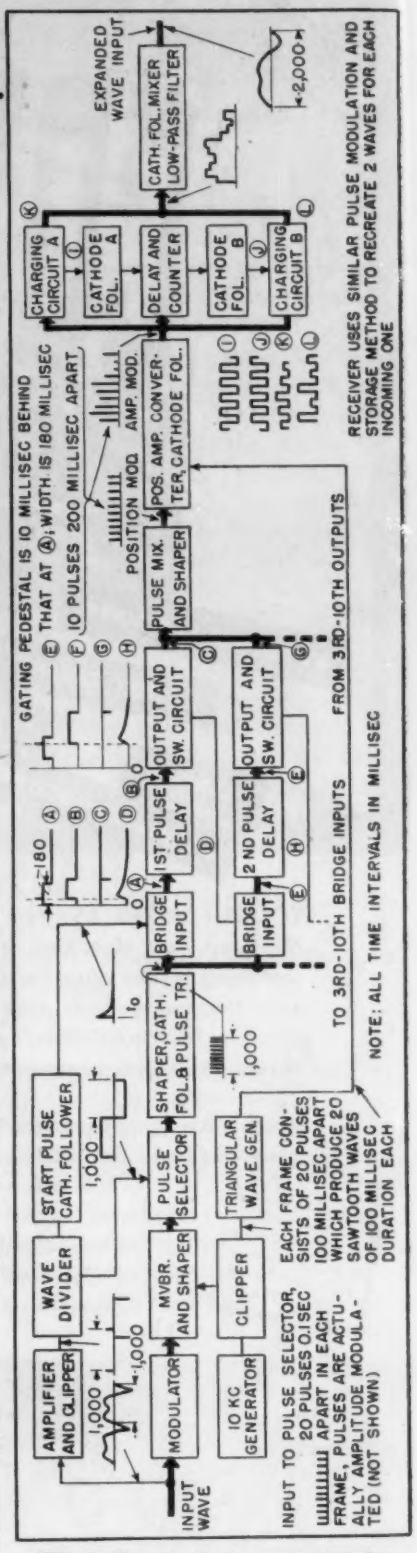
onds, and so on. Bridge circuits provide a means to gate the proper pulses into the delay circuits. The outputs from the delay circuits are fed to a mixer to obtain the pulse group corresponding to Fig. 1D. After delay, the pulses have normal (unmodulated) separations of 200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CATH. FOL. MIXER LOW-PASS FILTER
2,000
CHARGING CIRCUIT A
CATHODE FOL. A
DELAY AND COUNTER
CATHODE FOL. B
CHARGING CIRCUIT B
RECEIVER USES SIMILAR PULSE MODULATION AND STORAGE METHOD TO RECREATE 2 WAVES FOR EACH INCOMING ONE
GATING PEDESTAL IS 10 MILLISEC BEHIND THAT AT A; WIDTH IS 180 MILLISEC
10 PULSES 200 MILLISEC APART
POSITION MOD.
AMP. MOD.
POS. AMP. CONVERTER CATHODE FOL.
PULSE MIX. AND SHAPER
OUTPUT AND SW. CIRCUIT
OUTPUT AND SW. CIRCUIT
FROM 3RD-10TH OUTPUTS
180
1ST PULSE DELAY
2 ND PULSE DELAY
BRIDGE INPUT
BRIDGE INPUT
TO 3RD-10TH BRIDGE INPUTS
NOTE: ALL TIME INTERVALS IN MILLISEC
SHAPER, CATH. FOL. B PULSE TR.
1,000
START PULSE CATH. FOLLOWER
PULSE SELECTOR
TRIANGULAR WAVE GEN.
EACH FRAME CONSISTS OF 20 PULSES 100 MILLISEC APART WHICH PRODUCE 20 SAWTOOTH WAVES OF 100 MILLISEC DURATION EACH
WAVE DIVIDER
MVBR. AND SHAPER
CLIPPER
1,000
1,000
AMPLIFIER AND CLIPPER
MODULATOR
10 KC GENERATOR
INPUT WAVE
INPUT TO PULSE SELECTOR, 20 PULSES 0.1 SEC APART IN EACH FRAME, PULSES ARE ACTUALLY AMPLITUDE MODULATED (NOT SHOWN)

FIG. 2—Experimental wave expander

the SEEBURG MODEL "R"

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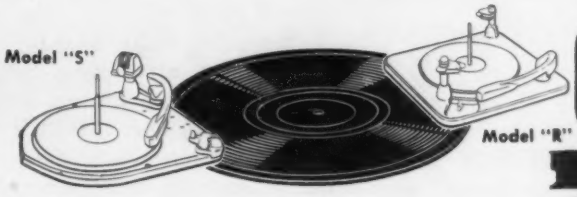

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Investigate *Brush* measuring devices before you buy . . . they offer more for your money.

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microseconds instead of the initial 100 microseconds. The modulation displacements of the individual pulses are unaffected.

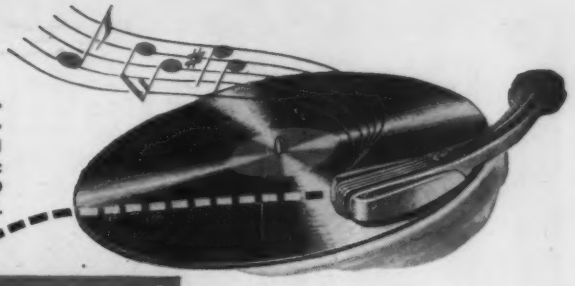
Because the number of pulses in each group may differ from the norm by ±1, the time interval between each delayed pulse group may be 200 ± 100 microseconds, and a special method of demodulation is required. The position-modulated pulses are converted to amplitude-modulated pulses by superimposing them on a 10,000-cps triangular wave. A capacitor charging circuit is used to gate and hold a charge corresponding to the amplitude of each pulse. Two charging circuits are used to avoid the gap created by discharging the capacitor. Switching actions of the charging circuits are actuated by two cathode followers controlled by a counter. Each incoming pulse trips the counter, which routes it to one capacitor and discharges the other. The expanded wave is obtained from the output of a low-pass filter.

Special Circuit Techniques

Because most of the circuit elements are conventional, it is unnecessary to describe their details. However, some of the design and adjustment techniques that are peculiar to this particular application should be mentioned.

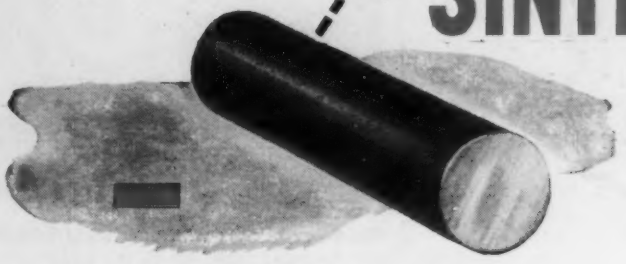
In the pulse modulator, which is essentially a one-shot multi-vibrator tripped by the negative pulse from a 10,000-cps source, the position of the tail edge of the pulse is position-modulated by the incoming signal, giving a ±6-microsecond displacement for a ±2-volt input signal. A differentiating circuit and shaper circuit transform the modulated edge into the leading edge of a pulse. Push-pull output for the bridges of the delay circuits is obtained from a pulse transformer that delivers a 5-microsecond pulse with a peak amplitude of 40 volts.

The pulse delay circuit is also a one-shot multivibrator delivering a pulse a preset interval after being tripped by one. A bridge is connected between each pulse delay circuit and the pulse source. Normally the bridges are balanced so that no pulses can reach the delay



The G-E Electronic Reproducer, which magnetically recreates the full recorded sound, derives its magnetic field from a G-E SINTERED ALNICO 5 permanent magnet.

Announcing... A NEW G-E DEVELOPMENT SINTERED ALNICO 5



Actual size of G-E SINTERED ALNICO 5 permanent magnet used in the G-E Electronic Reproducer is shown in red.

NEW ENGINEERING DEVELOPMENT

SINTERED ALNICO 5, General Electric's newest magnetic material, now enables you to design intricate shapes with higher external energy than ever before. The minimum guaranteed available energy is 3,500,000 gauss oersteds for most sizes and shapes. New G-E SINTERED ALNICO 5 possesses tensile properties several times those of CAST ALNICO 5 and can be produced economically in small size parts. You get better surface finish plus closer dimensional tolerances with new G-E SINTERED ALNICO 5.

NEW DESIGNS POSSIBLE

New SINTERED ALNICO 5 has higher external energy than either SINTERED ALNICO 2 or 4. This makes possible new designs heretofore impossible or impractical. It is especially adaptable where small powerful magnets having high magnetic properties are required. Because of their great stability and external energy, SINTERED ALNICO 5 magnets can save valuable space in your product. You can usually improve your product by re-designing to use high energy G-E SINTERED ALNICO 5. Typical applications now in production which use G-E SINTERED ALNICO 5 include the following: meters, relays, fountain pens, electronic reproducers, and compasses.

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YOU GET 5 ADVANTAGES

1. Higher external energy than either SINTERED ALNICO 2 or 4.
2. Tensile properties are several times greater than CAST ALNICO.
3. Excellent surface finish.
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Please send me:
( ) Technical Report on new SINTERED ALNICO 5.
( ) Bulletin, CDM-4, "G-E Permanent Magnets."

NAME..... TITLE.....
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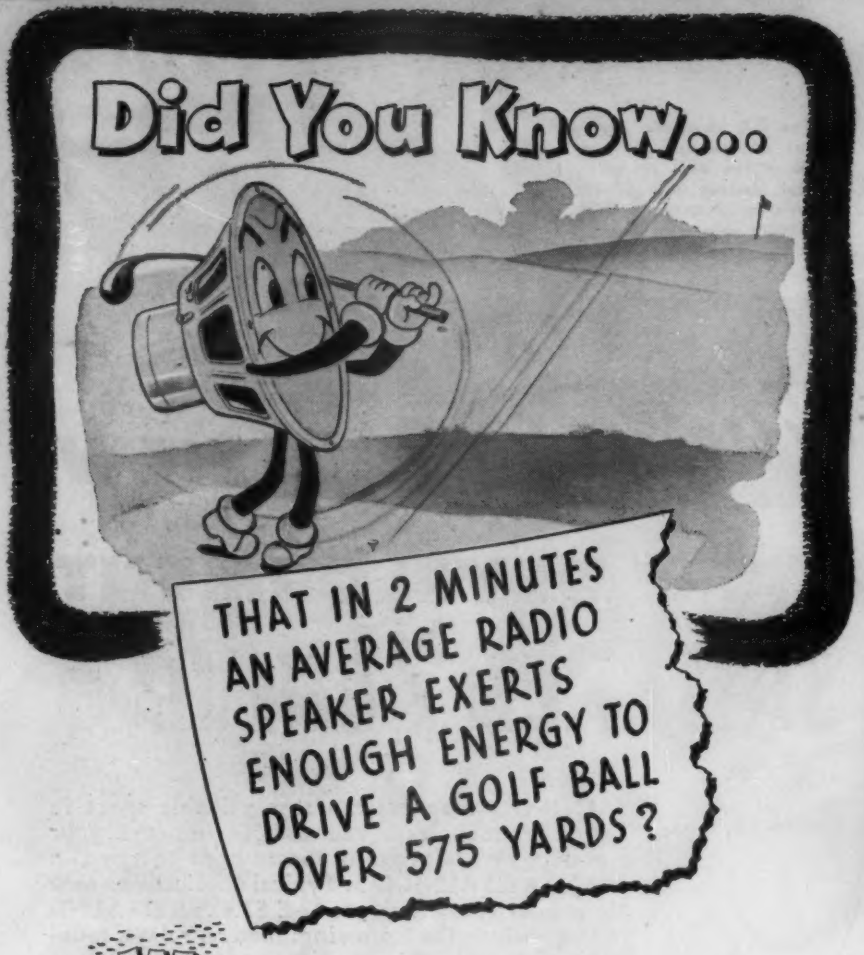
PRODUCTS MFRD.....
ADDRESS.....
CITY..... STATE.....

PERMANENT MAGNETS

GENERAL ELECTRIC

CD48-V2



We know it's impossible for a speaker to swing a golf club, but *it is true* that in just 2 minutes time an average loudspeaker does exert enough energy to drive a golf ball over 575 yards! This means that although OPERADIO builds speakers with the skill and care of a watchmaker . . . these speakers are sturdily constructed to stand up under heavy, continuous use. OPERADIO speakers are delicately balanced to authentically reproduce the sweetest high notes of a piccolo, yet, carry the tremendous power of a full orchestra crescendo.

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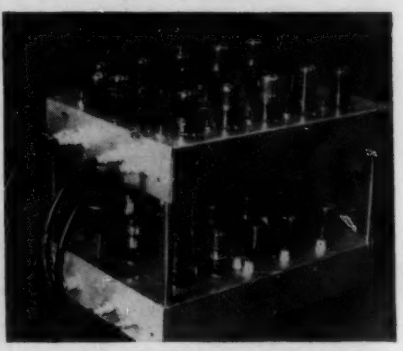
multivibrators. An incoming wave train initiates the action by producing a pulse that opens (unbalances) the first bridge circuit. The first pulse is thus received and delayed by the first circuit, and 10 microseconds later the bridge to the second delay is opened. The systematic switching continues routing successive pulses to delays in order. The unbalanced condition for each bridge exists for only 180 microseconds; the relay action stops when the incoming signal ceases.

Demodulation of the amplitude-modulated pulse train is compli-



Ten delay circuits with their input bridges and the pulse mixer are on the upper chassis. Coaxial cables connect to the lower chassis containing the rest of the experimental system for reducing bandwidth

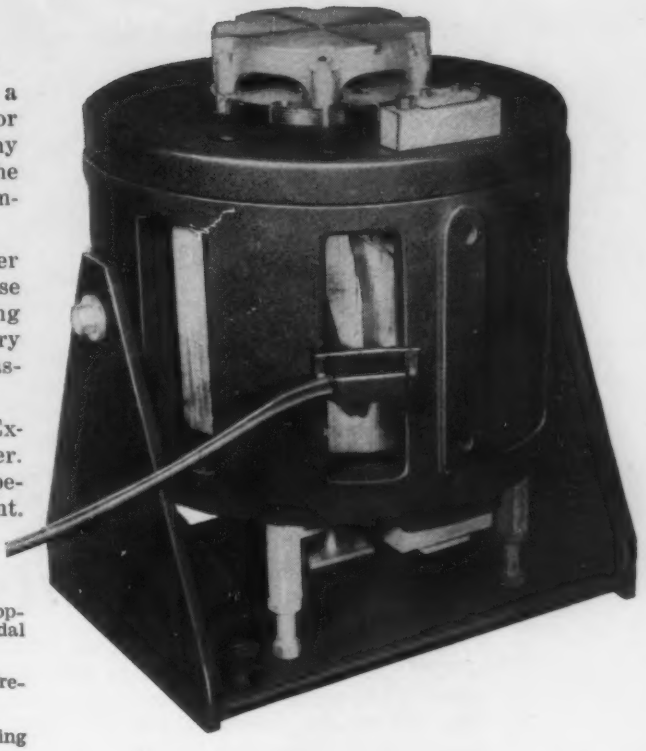
cated by the variation of the interval between pulse groups. Two charging circuits are used alternately to hold a charge that is proportional to the pulse amplitude. The charging circuits are controlled by square waves 180 degrees out of phase so that only one circuit can operate at a time. The surge of charging current in one circuit ignites a gas tube that discharges the other circuit. The pulse that controls the charging is delayed 10 microseconds and then passed to a counter to cause the square wave to reverse. The two capacitors of the charging circuits are connected to the grids of two cathode followers having a common load, and thus the capacitor with the larger voltage will control the output. The cathode voltage thus follows the envelope of the amplitude-modulated pulse train; the demodulated signal is obtained from a low-pass filter.

Limitations and Applications

The experimental equipment for

HOW TO USE VIBRATION
to shake the "bugs" out of your product

This MB Vibration-Exciter will do it for you . . . quickly . . . efficiently!



THERE ARE many ways you can put vibration to work for a better product. Use it for quality-control, or inspection, for example. With this MB Exciter, you can shake-test many electrical and mechanical products for defects — right on the production line. Or you can connect it to power-driven assemblies to locate rattles and hums — *and their sources.*

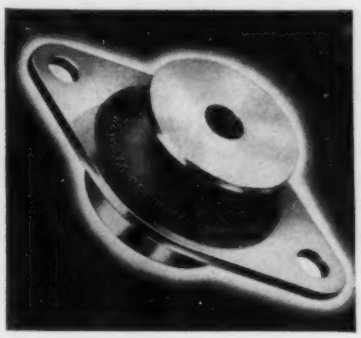
As an aid to research, this shaker is hard to beat for sheer usefulness. It reproduces vibrational effects of *years* of use within *hours!* Shake testing also shows whether operating conditions produce destructive resonance in any part. In every case, the "cure" is then easier, more accurate — and you assure a quieter, safer, longer-lasting product.

Many plants and laboratories are now using the MB Exciter for just such purposes. It pays for itself many times over. Why not write us about your "tough nut"? As vibration specialists, MB can show you how to crack it with this equipment.

PARTIAL TECHNICAL DATA

- Wide frequency range — 3 to 500 cps.
- Output — up to 200 pounds peak value.
- Power — 1500 v.a. maximum, continuous.
- Amplitude — 1-inch total excursion.
- Waveform—electrodynamic operation produces pure sinusoidal motion.
- Electrical adjustments—for frequency, force and amplitude.
- Smaller sizes available having wider frequency ranges.

IT'S EASIER DESIGNING WITH MB ISOMODE* MOUNTINGS



1. THEY ABSORB VIBRATION EQUALLY WELL IN ALL DIRECTIONS, so they control not only vertical, but troublesome horizontal and rocking motions as well.

2. THEY'RE NON-DIRECTIONAL. With an equal spring rate in all directions, they mount at any angle, giving you extra design freedom.

3. THEY HAVE HIGH LOAD-CAPACITY IN COMPACT SIZES, saving you space and weight.

4. THEY HAVE PLENTY OF RUBBER FOR SOFTNESS, yet are perfectly stable and safely self-snubbing.

Together with the tremendously simplified MB Design Method for positioning them, they offer you performance that makes satisfied customers. Send your vibration problems to MB if you want results. Our engineers are always ready to assist you.

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Bulletin on "Vibration Testing Technique." No. 4-5 provides helpful design information on mountings. Reprint of technical Paper describes Isomode Simplified Design Method. Write Dept. C-5.

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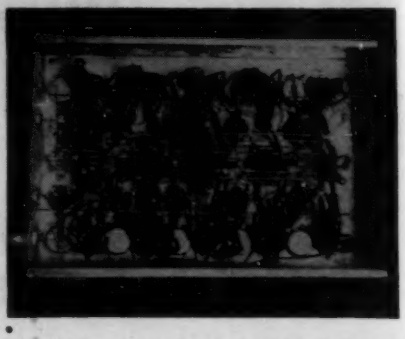


Parallel bars on the underside of the top chassis are used to minimize wiring capacitance to ground, thus improving the pulse response of the circuits. On the lower chassis shielded leads carry pulses to minimize interference

demonstrating the wave expanding principle has many limitations. The repetition rate limits the upper frequency that can be passed, while the number of pulses in a cycle limits the lower frequency. If the repetition rate of modulated pulses per second is r, and the lowest frequency to be transmitted is f_1, the maximum number of pulses in a cycle will be $N = r/f_1$ (inasmuch as fractions of pulses cannot be realized, the next largest integer value must be used for N). The experimental equipment used only ten delay circuits so that the fundamental frequency of the wave to be expanded could be no lower than 1,000-cps. Because the expanding circuit uses pulse position modulation it is subject to some small distortion.

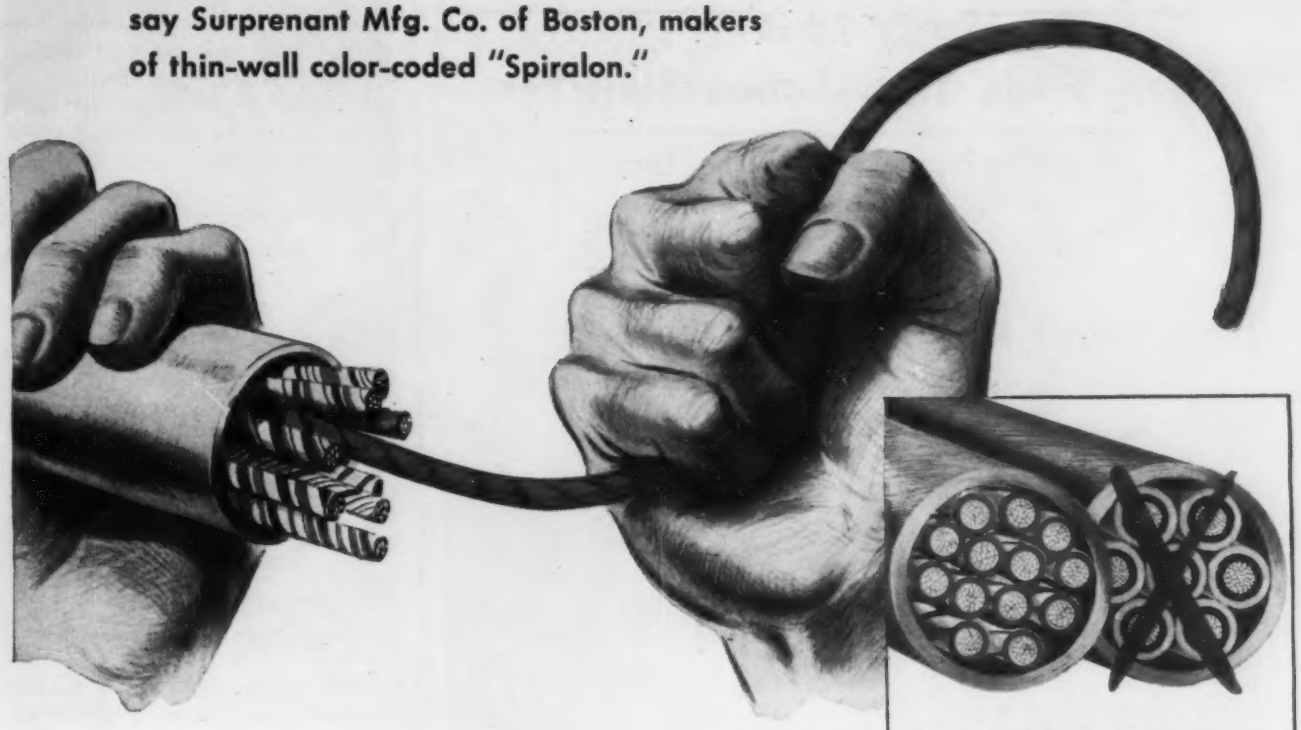
To extend the lower frequency to 100-cps (the fundamental frequency of the average male voice) so that the technique could be used for telephony, another method of pulse delay that would use fewer tubes would be desirable. To avoid distortion in the delay circuits, amplitude-modulated instead of position-modulated pulses might be used. Mercury delay lines might provide the solution. If the terminal equipment can be simplified, this method of transmission is a powerful means of providing more channels on existing wire lines and of solving the problem of frequency congestion in radio transmission.

The Polytechnic Institute of Brooklyn supplied the materials for building the test equipment. The author is also indebted to G. B.

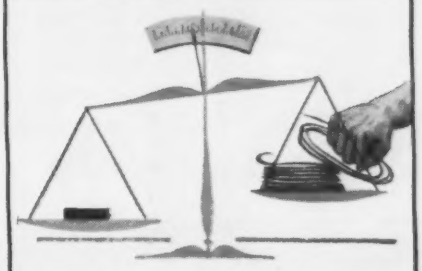
Why are big wire producers using Du Pont NYLON plastic?

"Unsurpassed as a protective jacket for wire,"

say Surprenant Mfg. Co. of Boston, makers of thin-wall color-coded "Spiralon."

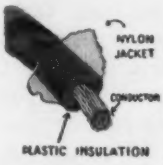


Wire has **SMALLER DIAMETER,** permits more wires in limited area.



Wire is **LIGHT IN WEIGHT,** and resists heat, oils, water, chemicals, abrasion and flexing.

"Jacketing of Du Pont NYLON helps us produce a color-coded wire with fungus- and abrasion-resistance, extra smoothness for easier pulling, and many other advantages."



"Our new 'Spiralon' wire is available in many thousands of distinct color combinations, making identification easy even in the most complex installations," report Surprenant Manufacturing Company. "It consists of a conductor, color-coded plastic insulation, and a transparent protective jacket of Du Pont nylon. The nylon cover can be applied easily and rapidly. It's *extra smooth.* It's tough and long lasting. It resists heat, oils, many chemicals, abrasion, and flexing. And nylon helps us produce a wire with *smaller diameter* and *lighter weight.* We feel it is unsurpassed as a thin-wall extruded covering."

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Wire, cable and many other electrical products today are *better* products, because of Du Pont nylon. This Du Pont plastic can be molded or extruded, and colored to fit specifications. For your own good—don't overlook its remarkable properties. Write for free booklet, "65 Success Stories of Product Improvement." Filled with helpful facts. Just address: E. I. du Pont de Nemours & Co. (Inc.), Plastics Dept., Room 146, Arlington, N. J.

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2. High tensile strength
3. Extreme toughness
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7. Ability to be molded or extruded . . . colored or in natural color.

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Important

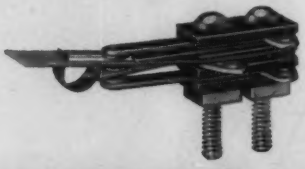
NOTICE

Acro's

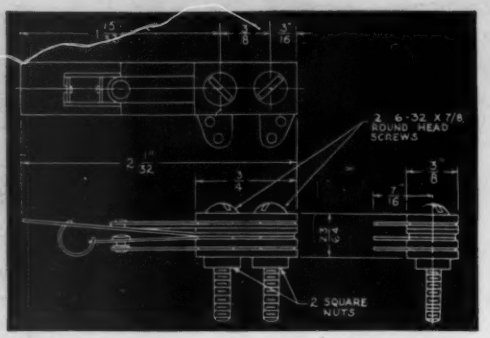
Open Blade Snap-Action Switches

Underwriters' Laboratories, Inc.
Inspected 15 Amps. 125 Volts
or 7½ Amps. 250 Volts A.C.

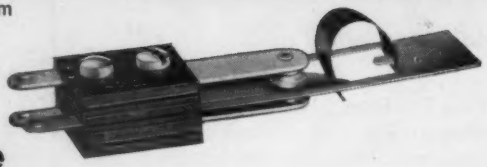
Small Single Pole Open Blade

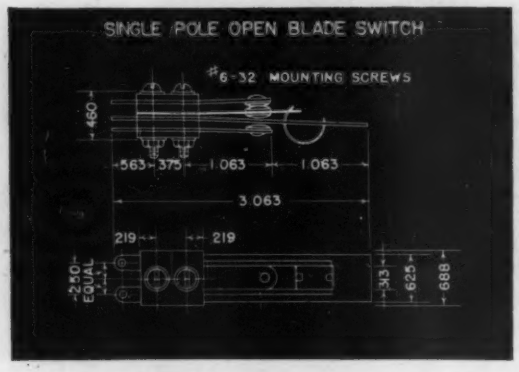


Yes, we repeat—these ACRO Open Blade Switches now carry Underwriters Laboratories, Inc., rating. The exceptionally fast Snap-Action of the patented ACRO Rolling Spring gives you freedom from burning contacts, more positive action and longer life. This switch, already used in hundreds of applications, has been designed to give the large volume user all the advantages of positive Snap-Action at low cost. Furnished with terminals at side or rear. Can be made with many variations in operating characteristics as well as form and length of blade.



Large Single Pole Open Blade





The larger single pole Open Blade Switch shown here, carries the same ratings as the small switch, but is of more rugged construction. Built with extra large contacts to assure extraordinary long life on applications where the continuous load is close to the rated load. Also built with the exclusive ACRO Rolling Spring principle for positive action and long, trouble-free life. Available with terminals at rear only, as illustrated.

Specifications for Both Models—Main blades of tempered spring steel. Rolling spring of beryllium copper. Contacts of fine silver. Switch locked together by two 6-32 screws. Furnished with either return type or set type action. For quick response, send operating details of your applications.

THE ACRO ELECTRIC COMPANY

1316 SUPERIOR AVENUE · CLEVELAND, OHIO

Hoadley and W. R. MacLean for their advice during the project.

Reproducing Handwriting

By Hugh Lineback
Assistant Professor
Oklahoma A & M
Stillwater, Okla.

A NOVEL application of the cathode-ray oscilloscope is the reproduction of handwriting. Inspiration for the device to be described came from a demonstration at the Naval School, Harvard University. Description of a similar device for writing "LORAN" (*Radio News*, Feb. 1946) attracted the attention

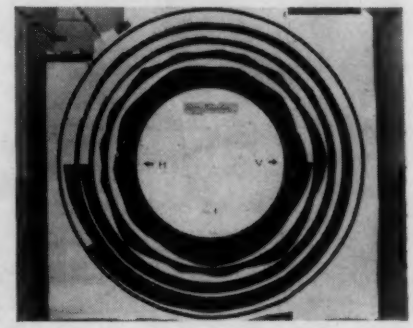


FIG. 1—Polar plot of handwriting

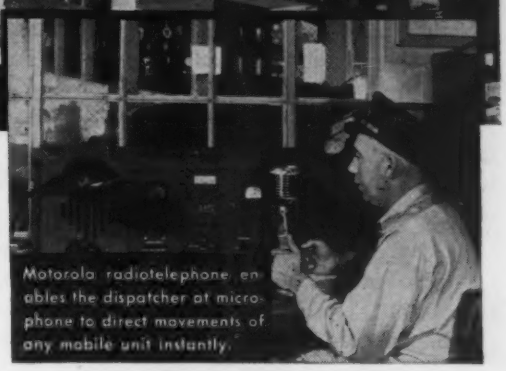
of a dealer who asked for a unit that would reproduce his letterhead as a novelty display while giving demonstrations of electronic equipment.

To reproduce the letterhead, it was enlarged on rectangular graph paper, using a projector and pantograph. Two hundred and forty points in each word were plotted in polar coordinates on a thirteen-foot circle, using separate tracks for vertical and horizontal components; Fig. 1 shows the result. A photographic transparency of this pattern was made and mounted on a motor shaft. The tracks were scanned by light beams with phototubes receiving the modulated light. The voltages developed by the

FIG. 2—Original and reproduction

Lock-In tubes in *Motorola* equipment maintain smooth flow of traffic on famous bridge

"Coming in with stalled car," radios tow truck operator. A mobile two-way FM radiotelephone permits instant communication with dispatcher.



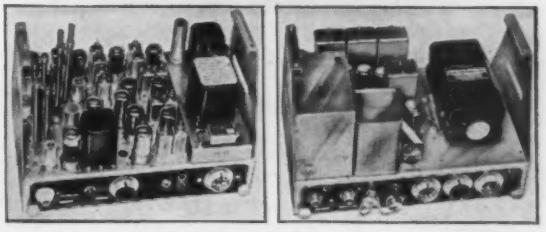
Motorola radiotelephone enables the dispatcher at microphone to direct movements of any mobile unit instantly.

THE famous San Francisco-Oakland Bay Bridge must be free of stalled cars at all times. A smooth flow of traffic is maintained with the aid of Motorola FM Radiotelephone equipment.

Tow cars, emergency roadside service trucks, electrician trucks, fire units and traffic engineer's sedan constitute the radio fleet. By means of this efficient system, a flow of 70,000 cars per day rolls with minimum delay over the great bridge.

Securely locked in position in the Motorola equipment are *Sylvania Lock-In Tubes*, depended upon day and night to give superlative service under all conditions!

For full information about Sylvania Lock-Ins see Sylvania Distributors or write Sylvania Electric Products Inc., Radio Tube Division, Emporium, Pa.



High frequency 160,000 kilocycle FM two-way Motorola radiotelephone equipment permits 100% radio coverage regardless of electrical interferences or steel enclosing structure. Sylvania Lock-Ins handle very high frequencies with ease. Have short, direct connections, fewer welded joints . . . no soldered joints — less loss; getter located on top; shorts eliminated by separation of getter material from leads! Cannot be dislodged from sockets no matter how rough the way.

SYLVANIA ELECTRIC

MAKERS OF RADIO TUBES; CATHODE RAY TUBES; ELECTRONIC DEVICES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES; ELECTRIC LIGHT BULBS

r-r-r-r-RIP!

"Embarrassing is no word for it! The big boss wants prints in an hour. He won't understand that this old tracing is dry and brittle, and hit high C when I tried to pull it out of the cabinet in a hurry. All he'll see will be the patch marks. Wonder why he doesn't insist on Arkwright."

Arkwright has a world-wide reputation for staying clear, clean and pliable, year after year . . . no ghost-producing spots . . . no tear-causing brittleness. Special mechanical all-the-way-through processing gives it this ability to laugh off the years. A perfect print was made recently from an 80-year-old tracing on cloth made by the same process now employed by Arkwright.

Why not try Arkwright? See for yourself what a difference there is. Generous working samples free upon request. Arkwright Finishing Company, Providence, R. I.

All Arkwright Tracing Cloths have these 6 important advantages

1. *No surface oils, soaps or waxes to dry out, stain and cause brittleness.*
2. *Erasures re-ink without "feathering" or "creeping".*
3. *Prints are always sharp and clean.*
4. *No pinholes or thick threads.*
5. *Tracings never discolor or become brittle.*
6. *Mechanical processing creates permanent transparency.*

Arkwright

TRACING CLOTHS

AMERICA'S STANDARD FOR OVER 25 YEARS

phototubes were applied to the two channels of the oscilloscope. Figure 2 shows the original letterhead and the reproduction produced on the oscilloscope. Actually only one word is reproduced at a time so that the letters can be as large as possible on the face of the cathode-ray tube. In use, either word can be selected or they can be made to alternate by an automatic relay.

Capacitor Counting Circuit

By BRADFORD HOWLAND
U. S. Naval Research Laboratory
(Author now at the Graduate School of Arts and Sciences, Harvard University, Cambridge, Massachusetts)

CONVENTIONAL capacitor counting circuits represent the count by a voltage stored on a capacitor. The circuit to be described operates on this principle but has in addition N stable states of electrical equilibrium and can store the count indefinitely. Because of this property of long time stability the circuit is well adapted to counting random events or at a low rate. A simple form of the circuit using crystal diodes is described.

Essentially the circuit consists of (A) a network of diodes and resistors, the complexity of which determines the number of equilibrium voltages, (B) an impedance sensitive feedback circuit that stabilizes the voltage across the capacitor at any one of the equilibrium voltages determined by the diode network, (C) means for stepping the capacitor voltage up or down one increment for each count, and (D) means for resetting the circuit to zero each time it has counted N events.

Basic Diode Charging Network

Figure 1 shows the basic two-terminal counting circuit composed of diodes, resistors, and batteries arranged for an N of 5. The resistances are large. Normally current flows from the high bias voltage through them and the bottom row of diodes. When a voltage of the polarity indicated is applied to the terminals of the network, the currents through the resistors will switch successively to the top row of diodes as the applied voltage exceeds the individual voltages to which the lower diodes are connected. This action results in the

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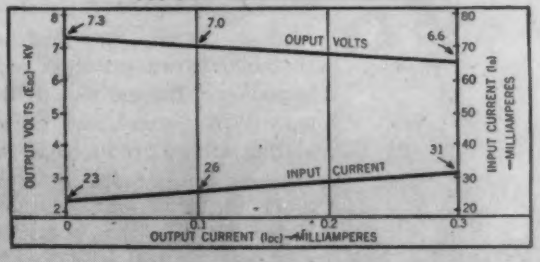

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***An unusual feature of this unit is that it may be used as the tank circuit of an audio oscillator. The input terminals are connected to the plate circuit. The 45-volt output terminals are connected as the grid feed back. The oscillator tube normally used is a 6V6. The operating frequency is 10,000 cycles.**

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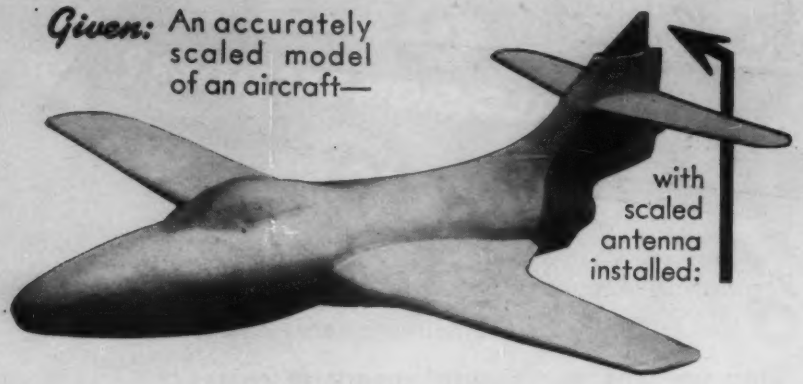

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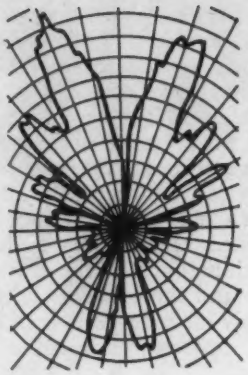

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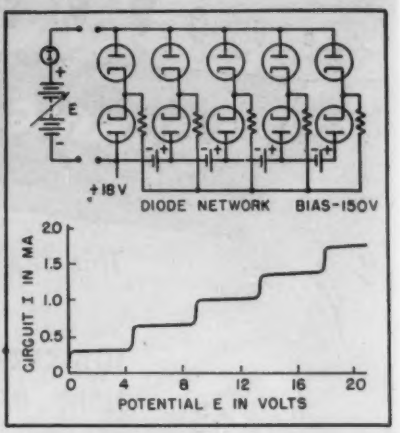

FIG. 1—Basic diode stepping circuit

current-voltage characteristic also shown in Fig. 1. This curve is based on measurements made with 1N34 crystal diodes, 470,000-ohm resistors, and a bias of −150 volts.

The characteristic of the network, as shown by its response curve, is such that its dynamic or a-c resistance, which is the reciprocal of the slope of the characteristic curve, is low near points of transition and high between them. At the transitions the resistance is about 700 ohms, between them it is approximately 50,000 ohms depending on the applied voltage and the back resistance of the diodes. It is this marked variation in a-c resistance of the network that is used by auxiliary circuits to stabilize the voltage across the capacitor.

Impedance Sensitive Circuit

The stabilizing circuit responds to changes in dynamic resistance of the network and controls the voltage across a capacitor at or near the value for which the network presents low impedance. One such circuit is shown in Fig. 2. A small r-f voltage is applied to the grid of an amplifier. The cathode of the amplifier tube is connected to ground through a high a-c impedance in parallel with the network. If the network presents a low a-c impedance, the cathode will be bypassed to ground and a large r-f output will be produced at the plate of the tube. If the network presents a high a-c impedance, the cathode degeneration will produce a small r-f output at the plate. In general this action is obtained only if the peak-to-peak r-f voltage is small enough to limit the voltage swings in the network within one

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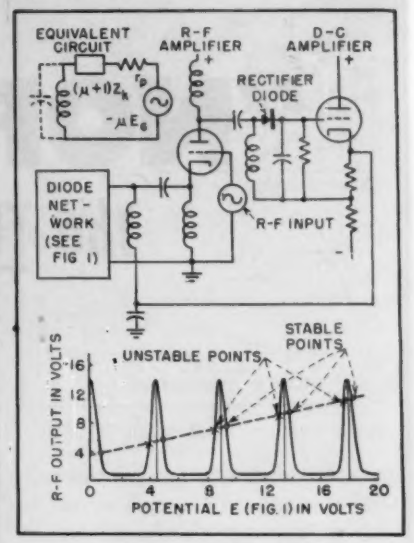


FIG. 2—Circuit stabilizes voltage

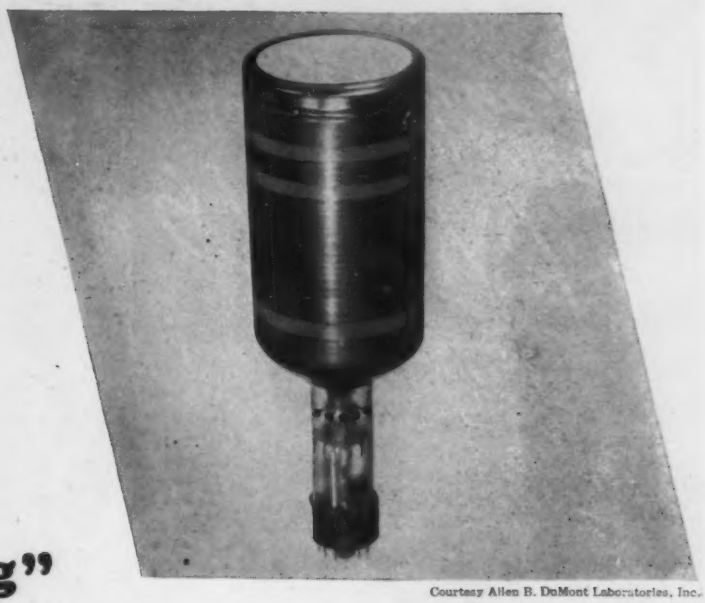
step of its dynamic characteristic.

The r-f output at the amplifier plate can be calculated by means of the equivalent circuit also shown in Fig. 2. The cathode impedance is Z_K. The curve in Fig. 2 shows this variation of plate r-f voltage with voltage applied to the network. This r-f voltage is rectified (by a crystal diode) to give a positive potential that is amplified and fed back to the capacitor to maintain whatever voltage is across it.

To discuss specifically how the stabilization operates, assume that the capacitor is charged to 9.5 volts. Should this potential decrease, the output from the r-f amplifier will increase, the grid of the d-c amplifier will be driven positive, and the voltage across the capacitor will be restored to its initial value. The action is actually quite complex and a minimum capacitance is required to obtain stable equilibrium points. There is, in addition, a stable condition when the capacitor voltage is negative, in which case the d-c amplifier is cut off; this state is not usually used in counting circuits.

Stepping and Reset Circuits

To step the voltage across the capacitor in performing the counting operation, an increment of charge is either added or subtracted; the stabilizing circuit then brings the capacitor voltage to the next equilibrium point. The points of unstable equilibrium on the stabilizing circuit characteristic are the dividing voltages between stable states. To drop the voltage



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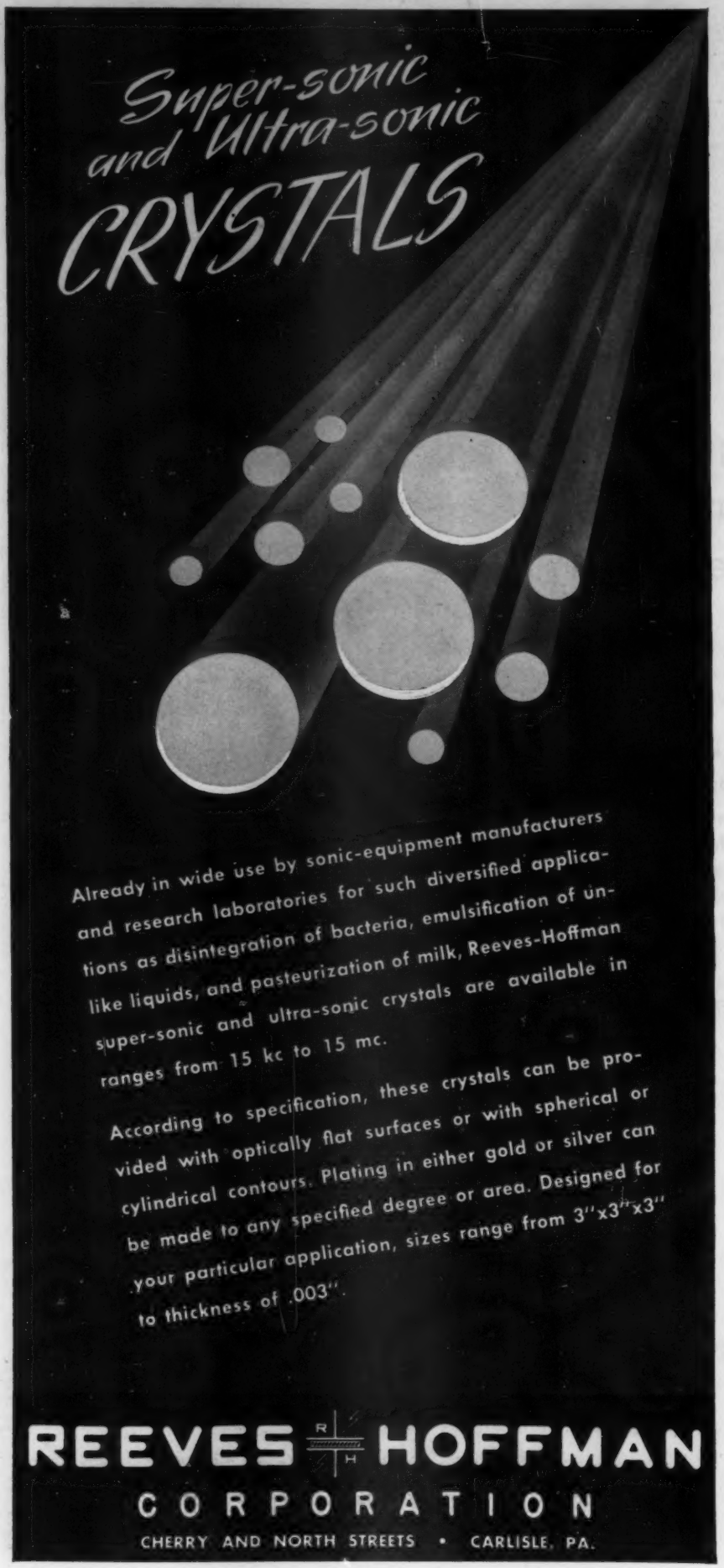
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across the capacitor to the next lower stable state the charge must be forcefully reduced to bring the voltage below the adjacent unstable point; to lift the voltage the charge must be increased to bring the voltage above the next unstable point before it will be driven into stability by the control circuit. The voltage across the capacitor is most easily stepped down as the drop to trigger the circuit to its next equilibrium is then small.

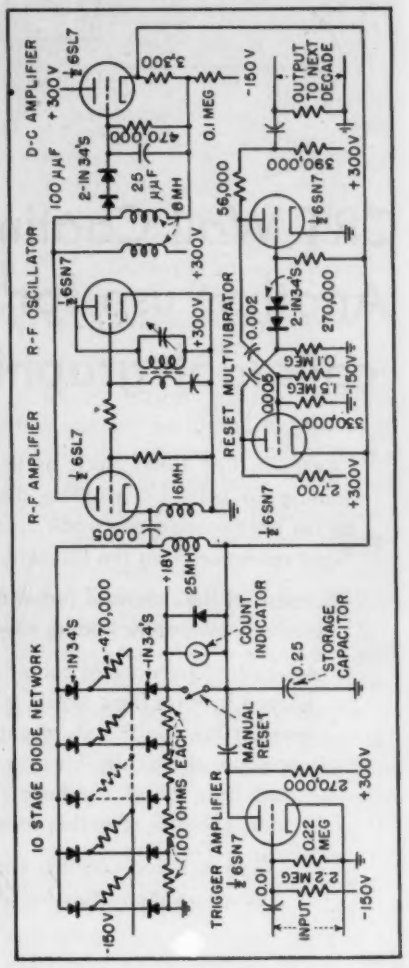

FIG. 3—Complete decade counting circuit

If the circuit is to count large numbers it must be reset to zero each time it has counted its limit of N pulses. A multivibrator or blocking oscillator that is triggered each time the voltage across the capacitor is stepped beyond its lowest (or highest) equilibrium can restore the circuit to zero. The output from the reset circuit is used to operate another counting circuit.

A complete decade counter using these elements is shown in Fig. 3. The network uses twenty 1N34

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crystal diodes, or 6AL5 vacuum diodes can be used equally well. Taps at 2-volt intervals along a low-impedance divider determine the ten equilibrium voltages. The number of steps that can be obtained in a single network is limited by the minimum voltage required per step (about 1 volt) and by the safe inverse voltage of the diodes. The control circuits require six triodes (three dual triode tubes). The r-f oscillator can be used in common by several other counting stages.

The oscillator frequency was chosen to make the plate circuit of the r-f amplifier resonate, and in this case is 600 kc. The inductance shunting the network was chosen to resonate with the stray capacitance to assure a high r-f impedance between stable states.

Positive pulses that are to be counted are applied to the storage capacitor through a trigger amplifier. The stored voltage is thus stepped down one 2-volt increment by each input pulse. The size of the coupling capacitor is not critical. The reset multivibrator is triggered each time the capacitor voltage goes negative. Upon being triggered the multivibrator passes a high current for a predetermined interval that restores the highest equilibrium voltage across the capacitor, limited at this value by the clipping diode. A positive output pulse from the multivibrator operates succeeding counting decades.

The count is indicated by a high-impedance voltmeter. A manual reset enables the circuit to be cleared. This circuit counts satisfactorily at any rate up to 1,500 events a second, the upper limit being determined by the reset time. The reset time, in turn, depends on the size of the storage capacitor and on the current that can be carried by the reset tube. The circuit of Fig. 3 does not represent an optimum design; it is believed that with further refinement the upper limit of counting speed can be considerably increased.

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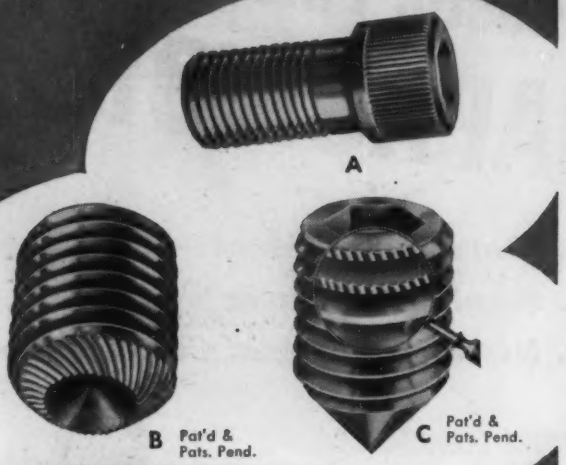

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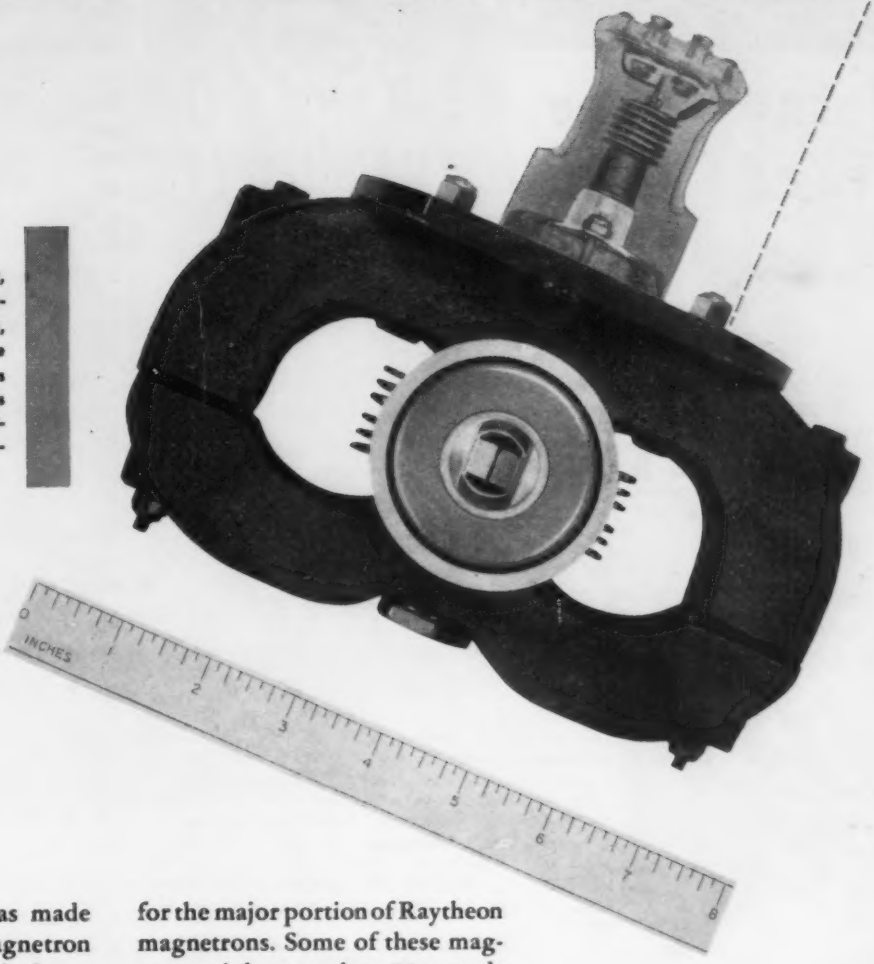

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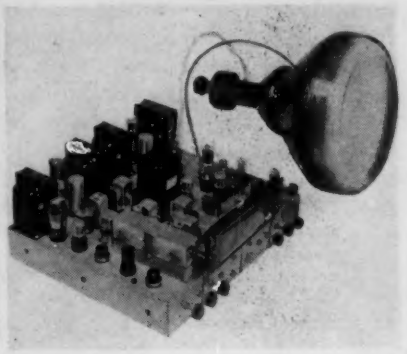

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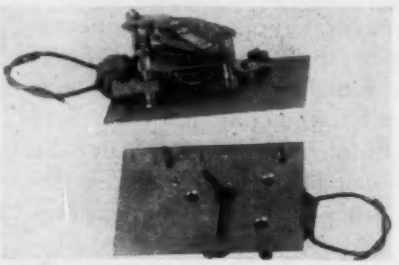
THE ARNOLD CLOCK CO., 136 W. 52nd St., New York, N. Y. The new precision timer has a single-circuit double-throw switch with a



capacity of 500 watts and can be used to turn any electrical unit either off or on. The electric switch has positive action that permits predetermined timing at any 15-minute interval.

Audio Amplification

LANGEVIN MFG. CORP., 37 W 65th St., New York 23, N. Y. Type 122 is an audio amplifier unit featuring plug-in channel adaptors which

MOMENT OF Uncertainty?

Certainly not...

a small rectifier has done its job!

Remember the old days when you used to push your starter button, and hope? Or, maybe, you're still doing it—if you haven't heard about the small charger that helps keep batteries at their peak. But many a car owner is now enjoying new confidence in his car, simply by letting this handy rectifier revive the battery when the car is in the garage. This same rectifier, incidentally, has numerous other applications in recharging 6-volt batteries.

Designing this rectifier to do its job right—making it small enough to sell easily, large enough to function properly—were engineering problems that came within the scope of General Electric engineers. In fact, General Electric's experience covers *all phases* of rectification problems—from rectifiers the size of an aspirin, to ten-ton rectifiers as big as your garage.

Tell G. E. your problem of d-c supply

When rectification problems come up—unusual problems, or even the routine problem of deciding *which type* of rectifier to use for a job—call on General Electric. Because General Electric makes all three—selenium, copper-oxide, and Tungar*—General Electric engineers can give you an impartial solution. Because G-E engineers know rectifiers for every type of application, they can give you the kind of *practical solution* you want. For information, write to Section A-11-631, General Electric Company, Bridgeport 2, Connecticut.

Selenium
Copper-oxide
Tungar
Rectifiers
G.E. makes all three

*TRADE-MARK REG. U.S. PAT. OFF.

GENERAL ELECTRIC

Maybe We've Got the Combination to Your Moulded Plastic Job

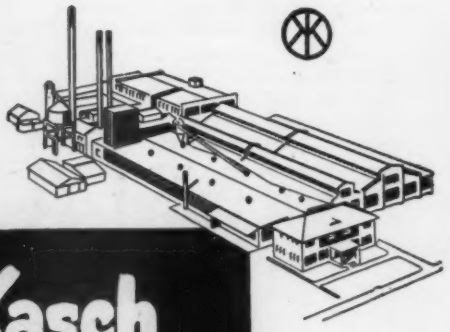
THERE'S no "Open Sesame" to a new moulding problem. It takes the same old patient hunt for the proper combination—in every function from design and engineering through mould-making, moulding, finishing and the rest.

But there's this bit of magic that still works. Knowing these problems . . . having solved similar puzzles before . . . experienced moulders are liable to get there quicker. And with methods that have been tried and proved.

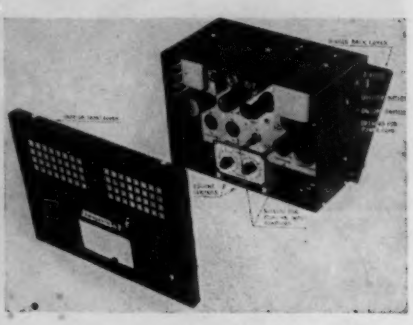
So look a little deeper than the price tag on your moulder's bid. Experience like ours — a reputation like ours — experienced personnel and a complete, self-integrated plant like ours—these things mean we'll quote a fair price on a job you can depend on quality-wise, cost-wise and delivery-wise.

We're interested in your business, if either compression, transfer or plunger moulding will do the job. May we send a sales engineer?

Kurz-Kasch, Inc.
1425 S. Broadway • Dayton 1, Ohio
BRANCH SALES OFFICES: New York, *Lexington 2-6677* • Chicago, *Harrison 5473* • Detroit, *Randolph 5214* • Franklin, Pa., *Venango County 186* • Los Angeles, *Prospect 7503* • Dallas, *Lakeside 1022* • St. Louis, *Rosedale 3542* Toronto, Canada, *Adelaide 1377.*
EXPORT OFFICES: 89 Broad Street, New York City, *Bowling Green 9-7751.*



Kurz-Kasch
FOR OVER 31 YEARS PLANNERS AND MOULDERS IN PLASTICS



provide it with eight applications. It has an output power of 8 watts with less than 3-percent total harmonic distortion from 50 to 15,000 cycles. An electrical characteristics chart will be supplied on request.

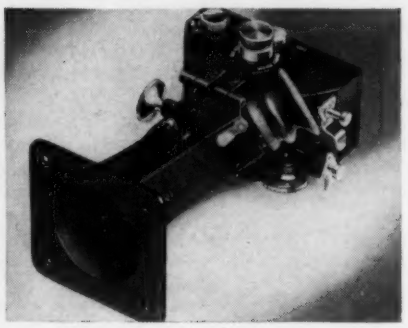
Counter Chronograph

POTTER INSTRUMENT CO., INC., 136–56 Roosevelt Ave., Flushing, N. Y. Model 450 interval timer will measure intervals in steps of 0.625

microsecond, corresponding to a frequency of 1.6 megacycles which is that of the crystal oscillator used as the time base. The instrument registers intervals up to 1 second. Longer periods are recorded by using an external counter.

Oscilloscope Camera

AMERICAN BRITISH TECHNOLOGY, INC., 57 Park Ave., New York 16, N. Y., distributors for Furzehill Laboratories, Ltd. Type 1684J oscilloscope camera uses unperforated



I-T-E Oval Resistor Assemblies are especially designed to meet the exacting and changing needs of the fast-growing electronics industry.

They are distinguished by their high unit-area wattage ratio which is due in part to the heat dissipation qualities of the mounting brackets. An oval resistor, or assembly of oval units, has a much higher wattage rating than that of a conventional round resistor of comparable size. This quality enables them to meet the requirements of limited space, and makes them particularly suited to compact aviation, sound, radio, and other modern electronics applications.

Oval Resistor Assemblies are part of I-T-E's complete line of wire-wound Power Resistors. Only the highest grade materials are used in their manufacture, and they are given the same thought in design, the same care in fabrication that the most complicated unit of switchgear receives.

No matter what your resistor problem calls for—compactness, long life, dependability, or exact tolerances—be sure to investigate I-T-E Oval Resistor Assemblies, the *modern* wire-wound Power Resistors. Complete technical information, as well as valuable application data, is contained in the new I-T-E Resistor catalog. Send for it today.

I-T-E OVAL RESISTORS

Type	Watts	Length	Maximum Recommended Resistance	Mounting Centers
108 Oval	30	1¼"	10000	2"
200 Oval	40	2"	15000	2¾"
316 Oval	55	3½"	25000	4¼"
424 Oval	65	4¾"	35000	5½"
600 Oval	75	6"	50000	6¾"

POWER RESISTORS

The Leader In Technical Excellence

I-T-E CIRCUIT BREAKER CO., RESISTOR DIVISION, 19TH & HAMILTON STS., PHILADELPHIA 30, PA.

SWITCHGEAR • UNIT SUBSTATIONS • ISOLATED PHASE BUS STRUCTURES • AUTOMATIC RECLOSING CIRCUIT BREAKERS • RESISTORS • SPECIAL PRODUCTS

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FOR THE HIGH-QUALITY PROFESSIONAL TYPE

Lear WIRE RECORDER

HIGH FIDELITY

Portable Model in Convenient Carrying Case

Includes AM Radio • Lear High-Fidelity Wire Recorder • Leartronic Scratch Filter • Single Record Phonograph Turntable with Leartron Pickup • Dynamic Speaker • Microphone.

One Full Hour Spool of Wire with Cue Disc • Index Pads • Connection Cable to attach Lear High-Fidelity Wire Recorder to any radio or loud speaker. Radio time clock, headphones, and additional spools available as accessories.

generous discount arrangements for qualified representatives

CHECK THESE IMPORTANT FEATURES

- A precision instrument
- Built by experienced engineers
- Full range of high and low tones
- Easy to operate and use
- Hours of uninterrupted performance
- Automatic timer
- Complete range of models and prices, with and without AM-FM Radio
- Super-fast rewind
- Wire can be used over and over
- Records direct, or from phonograph, radio
- Nationally advertised

Ideal for Radio Stations • Advertising Agencies Auditions • Air Checks • Remote Broadcasts Public Events • Schools & Colleges Dramatic & Voice Teachers Language Schools • Courts & Police, etc.

We have begun a nation-wide campaign of publicity and advertising that will create steady and profitable demand for the LEAR high-fidelity wire recorder. You can share in these sales and profits *while calling on your present trade!* **If you are an independent** radio supply salesman—or, if you operate a radio supply business with a live-wire sales staff—you can make money selling the LEAR High-Fidelity Wire Recorder. **We have a most attractive** deal for you now—if you are ready to do a REAL SELLING JOB! No middlemen or distributors—this is a direct factory deal where you get the full discounts!

For complete details, send information about yourself, your organization and your territory TODAY—to Dept. C.

Lear

INCORPORATED

110 Ionia Ave. N. W., Grand Rapids 2, Mich.

35-mm film. Equipped with an f/1.9 lens, the camera can be converted to a continuous film type.

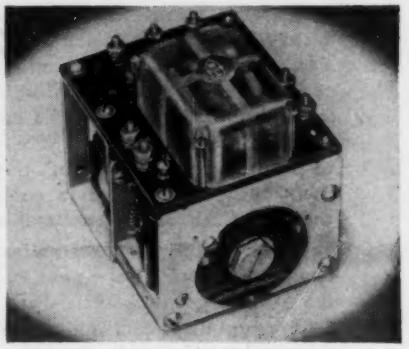
Bidirectional Microphone

TURNER CO., Cedar Rapids, Iowa. Model 87 velocity microphone uses a single element ribbon generator

supported in an Alnico V magnet. Response is within plus or minus 5 db from 80 to 10,000 cycles. Level is 62 db below 1 volt per dyne per square centimeter at high impedance. A switch allows use into 50, 200, or 500 ohms.

Timing Relay

WARD LEONARD ELECTRIC CO., Mount Vernon, N. Y., announces development of the Bulletin 362 mo-



tor driven time delay relay with composite connections. The unit is designed for use in control equipment or systems where an adjustable time delay is required for proper remote, automatic or sequential operation.

Lightning Arrester

RADIO CORP. OF AMERICA, Camden, N. J., has developed a lightning

MONEY BACK GUARANTEE We believe units offered for sale by mail order should be sold only on a "Money-Back-If-Not-Satisfied" basis. We carefully check the design, calibration and value of all items advertised by us and unhesitatingly offer all merchandise subject to a return for credit or refund. You, the customer, are the sole judge as to value of the item or items you have purchased.

The Model 88—A COMBINATION

SIGNAL GENERATOR AND SIGNAL TRACER

The Model 88 comes complete with all test leads and operating instructions.

ONLY **$28.85** NET

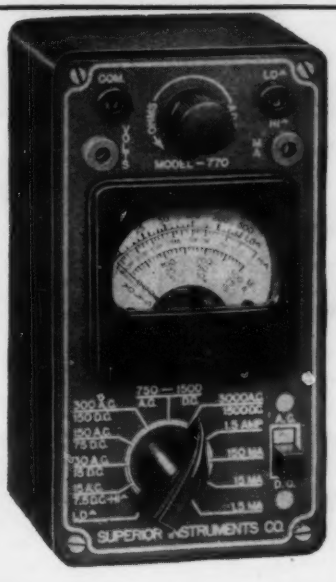
We're prepared for the demand we know will be created by this long overdue combination of the two units which have always been used together. The ultimate in signal tracing procedure is achieved by the Model 88, for the use of this model, enables you to use either the broadcast signal itself or the signal injected by the Signal Generator. This is especially useful of course when servicing "dead" or "intermittent" receivers. The Model 88 you will find is the greatest time-saver ever provided for by combining a full range Signal Generator and Signal Tracer into one unit the set up time for interconnecting, etc., is entirely eliminated.

Signal Generator Specifications:

★ Frequency Range: 150 Kilocycles to 50 Megacycles.
★ The R.F. Signal Frequency is kept completely constant at all output levels. This is accomplished by use of a special grid loaded circuit which provides a constant load on the oscillatory circuit. A grounded plate oscillator is used for additional frequency stability.
★ Modulation is accomplished by Grid-blocking action which has proven to be equally effective for alignment of amplitude and frequency modulation as well as for television receivers.
★ Positive action attenuator provides effective output control at all times.
★ R.F. is obtainable separately or modulated by the Audio Frequency.

Signal Tracer Specifications:

★ Uses the new Sylvania 1N34 Germanium crystal Diode which combined with a resistance-capacity network provides a frequency range of 300 cycles to 50 Megacycles.
★ Simple to Operate—Clips directly on to receiver chassis, no tuning controls.
★ Provision is made for insertion of phones of any impedance, a standard Volt-Ohm Milliammeter or Oscilloscope.



The New Model 770—AN ACCURATE POCKET-SIZE

VOLT-OHM-MILLIAMMETER

(Sensitivity 1000 Ohms per volt)

Features: • Compact-measures 3-⅛" x 5-⅞" x 2-¼" • Uses latest design 2% accurate 1 Mil. D'Arsonval type meter. • Same zero adjustment holds for both resistance ranges. It is not necessary to readjust when switching from one resistance range to another. This is an important time-saving feature never before included in a V. O. M. in this price range. • Housed in round-cornered, molded case. • Beautiful black etched panel. Depressed letters filled with permanent white, insures long-life even with constant use.

Specifications:

6—A. C. VOLTAGE RANGES:
0—15/30/150/300/1500/3000 Volts

6—D. C. VOLTAGE RANGES:
0—7½/15/75/150/750/1500 Volts

4—D. C. CURRENT RANGES:
0—1½/15/150 Ma. 0—1½ amps.

2—RESISTANCE RANGES:
0—500 ohms 0—1 Megohm

The Model 770 comes complete with self-contained batteries, test leads and all operating instructions.

ONLY **$13.90** NET

20% DEPOSIT REQUIRED ON ALL C.O.D. ORDERS

GENERAL ELECTRONIC DISTRIBUTING CO.

DEPT. E6 98 PARK PLACE,
NEW YORK 7 N. Y.

Simple New *Solderless* Couplings

Maintain Constant 51.5 Ohm Impedance

ANDREW *Flanged* COAXIAL TRANSMISSION LINE FOR FM-TV

ANDREW

Offering the dual advantage of easy, solderless assembly and a constant impedance of 51.5 ohms, this new ANDREW FM-TV line is available in four diameters. Each line fully meets official RMA standards. It also is recommended for AM installations of 5 Kw or over.

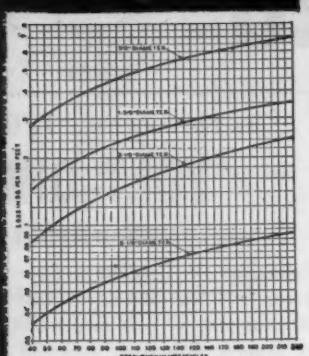
Fabricated in twenty foot lengths with brass connector flanges silver brazed to the ends, sections are easily bolted together. A circular synthetic rubber "O" gasket effectively seals the line. Flux corrosion and pressure leaks are avoided. A bullet-shaped device positively connects inner conductors.

Close tolerances are maintained on characteristic impedance in both line and fittings, assuring an essentially "flat" transmission line system.

Mechanically and electrically better than previous types, this new line has steatite insulators of exceptionally low loss factor. Both inner and outer conductors of all four sizes are of copper having very high conductivity.

Flanged 45 and 90 degree elbow sections, and a complete line of accessories and fittings available.

Better be safe, than sorry. Avoid costly post-installation line changes. Get complete technical data, and engineering advice, from ANDREW now.



ATTENUATION CURVE

shows total loss plus 10% derating factor to allow for resistance of joints and deterioration with time.

Four diameters available: 6⅛"—3⅛"—1⅝" and ⅞".

Andrew CORPORATION

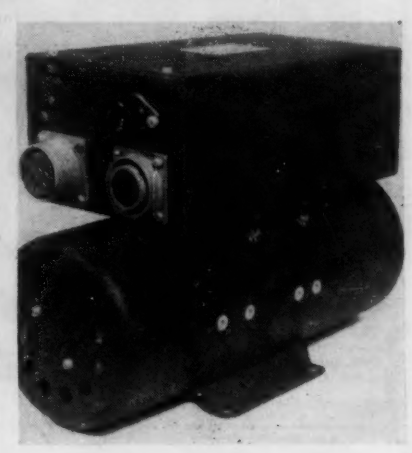
363 EAST 75th STREET · CHICAGO 19

Pioneer Specialists in the Manufacture of a Complete Line of Antenna Equipment

arrester designed to fit into television and f-m receiver installations. The device features a new method of attaching the transmission line which avoids cutting and splicing.

Regulated Dynamotor

BENDIX AVIATION CORP., Red Bank, N. J., introduces a regulated dynamotor which permits constant out-



put with as much as 25-percent variation in input voltage. The unit is available in various sizes and voltage ratings.

Audio Frequency Meter

BARKER & WILLIAMSON, INC., 237 Fairfield Ave., Upper Darby, Pa. Model 300 audio frequency meter makes direct measurements of unknown audio frequencies up to 30,-

Imitated But Never Equaled

THE INTERNATIONALLY FAMOUS MECANITRON HIGH SPEED INK TAPE RECORDER

Model MA-126 Series

The model MA-126 series recorder represents a complete, self-contained high speed ink tape recording system. The Mecanitron recording head represents a new departure in moving coil design. A lightweight, rugged coil of eight ohms impedance is driven by a special polar, pulse amplifier.

SPECIFICATIONS

MECHANICAL

Watch case construction—entire head may be removed by loosening one thumbscrew.
Tape guide arm provides straight line feed and floating action at the penpoint. This member is also instantly removable for cleaning.
Primary and secondary stops adjustable for any desired character width.
Pen and pen bearings instantly removable.
Pen may be cleaned quickly using straight piece of cleaning wire.
Plastifloat bearings used throughout requiring no lubrication.
Natural period of pen linkage well above 1,000.
Permanent magnet field requiring no excitation, resulting in cool operation.
Deep draft non-spilling ink well.
Micrometer barrel tape vernier adjustment.
Entire head dis-assembled in 30 seconds.
Completely tropicalized.

ELECTRICAL

Output power pulses instantly adjustable for any speed and independent of input signal voltages.
Phase reversing power output switch.
Power output tubes draw no current during signal standby periods.
Screen grid control trigger action in DC amplifier circuit.
Automatic noise limiting bias control in full wave rectifier circuit.
Complete automatic volume control.
All circuits voltage regulated.
Standby switch may be controlled by tape puller.
Built in multi-contact relay switch controlled by tape tension allowing standby recorders and/or associated circuits to instantly function upon tape depletion.

Four separate and distinct inputs are available as follows:

a. Tone input: This input accepts any tone signal between 700 and 5,000 cycles at Zero DB or more.
b. Teletype: This input accepts the output from a teletype printer and prints teletype characters on inked tape suitable for retransmission at higher speeds by use of a Mecanitron Scanner.
c. Frequency shift: This input allows operation from the discriminator circuit of any standard F.M. receiver, or the detector circuit of any standard AM receiver.
d. Contact: This input allows operation of the recorder by means of any standard telegraph key, permitting the production of inked tape for retransmission.

Mecanitron high speed recorders can be obtained in either single or dual units. Dual units are sometimes required to permit operation of a second unit in standby position for instant use, as the tape in the first unit is used up. Instantaneous changeover makes operation possible without breaks. These units may be supplied for rack mounting if desired.

Write for additional information today!

MECANITRON CORPORATION

General Offices: 8 Irvington Street, Boston 16, Mass.

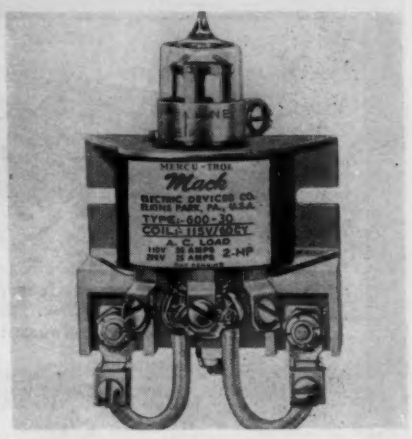
Phone: COmmonwealth 6-2639

Branches: 1011 New Hampshire Avenue, Washington 7, D. C., NAtional 0310
142 Bank Street, Ottawa, Ont., Canada, Phone: Ottawa 5-5590

000 cycles. Six ranges are required for the complete coverage of this spectrum. The meter will operate on any waveform with peak ratios of less than 8 to 1, and requires a minimum input of 0.5 volt.

Power Relays

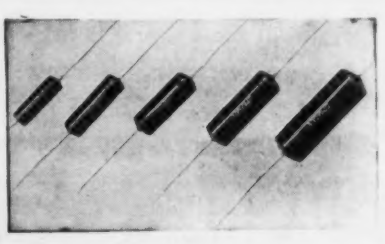
MACK ELECTRIC DEVICES, INC., 30 Glenside Ave., Wyncote, Pa., has developed the Mercu-Trol power



relays with 3-coil terminals and featuring a replaceable tube which is hermetically sealed with the contacts, having mercury-to-mercury make and break in inert gas. Contact ratings and coil data may be found in bulletin 410.

Molded Tubular Capacitors

SPRAGUE ELECTRIC CO., North Adams, Mass. Available in all popular capacitance values in 200 to 1,600-



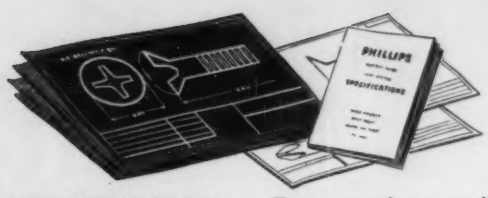
volt types, new phenolic molded tubular capacitors are rated for operation from minus 40 to plus 85 C. They are described in Bulletin 210.

Automatic Washing Unit

RAYTHEON MFG. CO., 60 E. 42nd St., New York 17, N. Y. The new automatic washing unit for use on industrial precipitators washes and

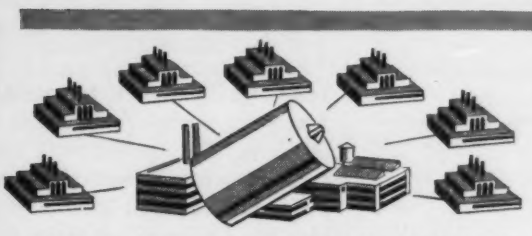
ONLY PHILLIPS RECESSED HEAD SCREWS

OFFER DIMENSIONAL UNIFORMITY INSURED BY CLOSE ENGINEERING CONTROL

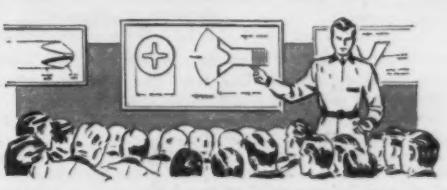


ESTABLISHED STANDARDS . . . Every manufacturer of Phillips Cross Recessed Head Screws is supplied with complete engineering and production data which prescribes precise dimensions and tolerances.

CENTRALIZED PRODUCTION TRAINING . . . And, before production is started on Phillips Screws, each plants' supervisory staff puts in an extended training period with Phillips engineers.



COMMON SOURCE OF RECESS FORMING TOOLS . . . Punches for forming the Phillips Cross Recess in all types and sizes of Phillips Screws are formed from master types at one plant. The manufacture of gauges for maintaining uniformity of Phillips Drivers and Bits are similarly centralized.



ENGINEERS' MEETINGS . . . Standards carefully established at the very beginning are rigorously maintained through meetings of "Phillips Recessed Head Standards Committee". Engineers from all plants meet to exchange ideas, discuss problems and learn about recent developments.

All these precautions to secure absolute dimensional uniformity are just part of the care taken to produce Phillips Cross Recessed Head Screws that give users *all* the advantage of a cross recess engineered for practical production.

Speed and ease of driving in production assembly demands that the driver and recess fit smoothly, perfectly, the same way every time, all the time. With Phillips Screws, you can depend on it.

GET ALL THE ADVANTAGES OF ASSEMBLY WITH CROSS RECESSED HEAD SCREWS . . .

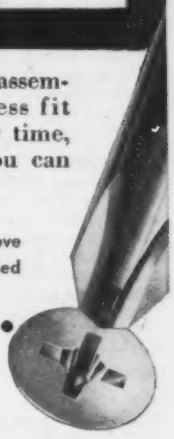
GET **PHILLIPS** *Recessed Head* **SCREWS**

Wood Screws · Machine Screws · Self-tapping Screws · Stove Bolts

25 SOURCES

American Screw Co.
Central Screw Co.
Continental Screw Co.
Corbin Screw Div. of American Hdwe. Corp.
Elco Tool & Screw Corp.
The H. M. Harper Co.
Lamson & Sessions Co.
Milford Rivet and Machine Co.
National Lock Co.
National Screw & Mfg. Co.
New England Screw Co.
Parker-Kalon Corporation
Pawtucket Screw Co.
Pheoll Manufacturing Co.
Reading Screw Co.
Russell Burdsall & Ward Bolt & Nut Co.
Scovill Manufacturing Co.
Seaboard Screw Corp.
Shakeproof Inc.
The Southington Hardware Mfg. Co.
The Steel Company of Canada, Ltd.
Sterling Bolt Co.
Stronghold Screw Products, Inc.
Wales-Beech Corp.
Wolverine Bolt Company

GET THIS NEW BOOKLET of facts that prove the top value, top economy of Phillips Recessed Head Screws. It's free . . . use the coupon.



Phillips Screw Mfrs.,
c/o Horton-Noyes Co.
1800 Industrial Trust Bldg.
Providence, R. I.

Send me the new booklet—"How to Select Recessed Head Screws for Practical Production Driving".

Name _____

Company _____

Address _____ E-29

ELECTRONICS — *June, 1948* 201

How 19,000 companies up take-home pay *without upping payrolls*

Can you deduct $18.75 from $60.00 and get $66.25? *Yes.* And the way you can do it is mighty important to your company—and to the nation!

You start with $60, representing someone's weekly take-home pay. You deduct $18.75 for the purchase of a U.S. Savings Bond. That leaves $41.25. But $41.25 isn't what the worker takes home. He takes home $41.25 *plus a $25 Savings Bond.* Total (assuming he holds the Bond till maturity): *$66.25.*

WHAT 19,000 COMPANIES HAVE LEARNED

In the 19,000 companies that are operating the Payroll Savings Plan for the regular purchase of Savings Bonds, employees have been more contented in their jobs—absenteeism has decreased—even accidents have been fewer!

Those are the "company" benefits the Plan provides, in addition to extra security for individual employees.

But the Plan has other, far-reaching benefits of basic importance to both your business and the national economy . . .

SPREADING THE NATIONAL DEBT HELPS SECURE YOUR FUTURE

The future of your business is closely dependent upon the future economy of your country. To a major extent, that future depends upon management of the public debt. Distribution of the debt as widely as possible among the people of the nation will result in the greatest good for all.

How that works is clearly and briefly described in the free brochure shown at the right. Request your copy—*today*—from your State Director of the U. S. Treasury Department's Savings Bonds Division.

ACTION BY TOP MANAGEMENT NEEDED

The benefits of regular Bond-buying are as important today as ever—but war-time emotional appeals are gone. Sponsorship of the Payroll Savings Plan by a responsible executive in your company is necessary to keep its benefits *advertised to your employees.*

Banks don't sell Savings Bonds on the "installment plan"—which is the way most workers prefer to buy them. *Such workers want and need the Payroll Savings Plan.*

Those are the reasons why it's important to make sure that the Plan is adequately maintained in your company.

The State Director will gladly give you any assistance you wish.

"The National Debt and You,"

a 12-page pocket-size brochure, expresses the views of W. Randolph Burgess, Vice Chairman of the Board of the National City Bank of New York—and of Clarence Francis, Chairman of the Board, General Foods Corporation. Be sure to get your copy from the Treasury Department's State Director, Savings Bonds Division.

The Treasury Department acknowledges with appreciation the publication of this message by

ELECTRONICS

This is an official U.S. Treasury advertisement prepared under the auspices of the Treasury Department and the Advertising Council

ELECTRONICS — *June, 1948* 203

Out on a limb because of shortages?

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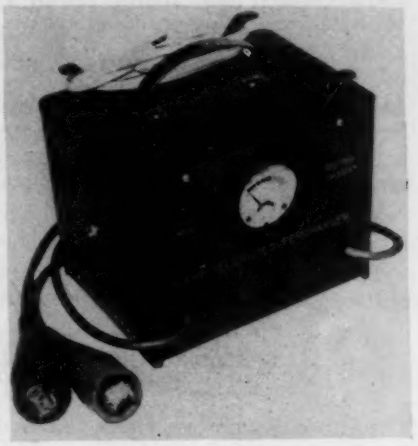
RICHARDSON-ALLEN CORP., 15 West 20th St., New York, N. Y., has introduced a new line of small, light,



portable battery chargers. Each unit features a direct-reading meter, circuit-breaker protection and selenium rectification. They operate on 110 volts, 50 to 70 cycle a-c current.

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RELIANCE ELECTRIC & ENGINEERING CO., Cleveland, Ohio. An electronic excitation control system has been designed for closely controlled speed regulation. Functionally it is comparable to a 2-circuit, motor operated rheostat with a servomechanism, preset speed device controlling the output voltage

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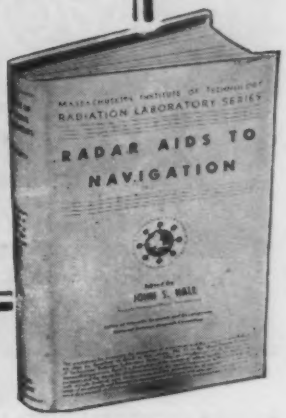

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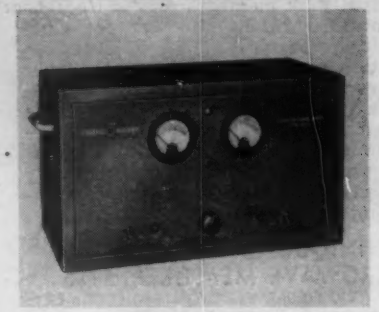

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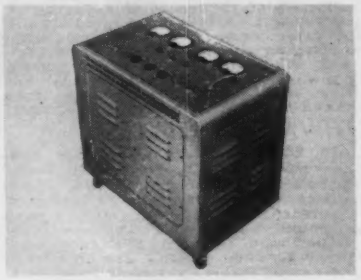

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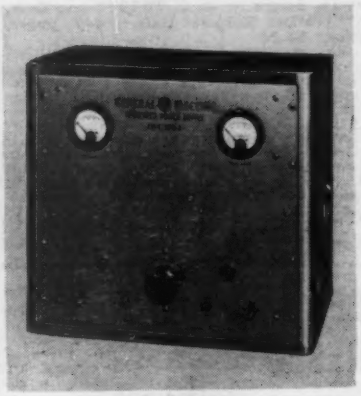

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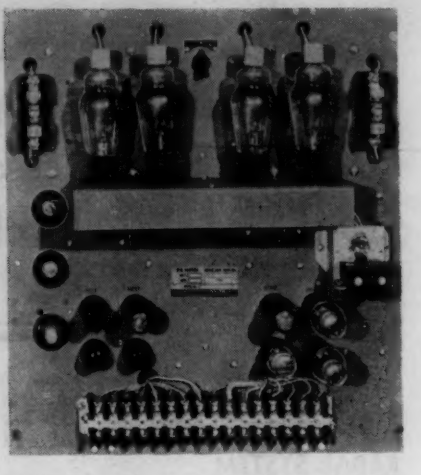

of a constant potential rotating exciter. A single-phase half-wave rectifier with a back rectifier is recommended for use with the unit. Output voltage can be varied from 0 to 230 volts.

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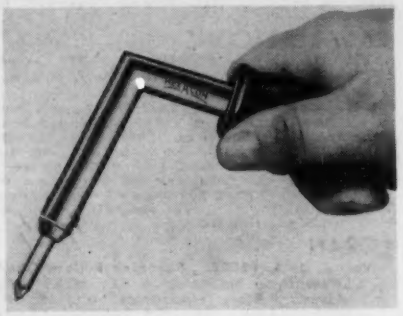

transformer for operation. It works from any regular 110 or 220-volt line circuit a-c or d-c. Designated as catalog No. 30H, list price is $5.00.

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CORNELL-DUBILIER ELECTRIC CORP., South Plainfield, N. J. The DSTH television capacitors are oil-impreg-

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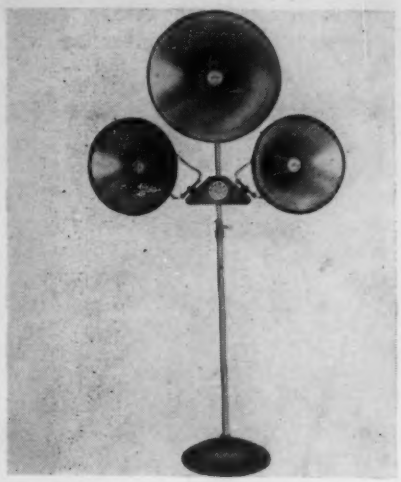
ATLAS SOUND CORP., 1443 39th St., Brooklyn 18, N. Y. This stand and mounting fixture permit the illus-



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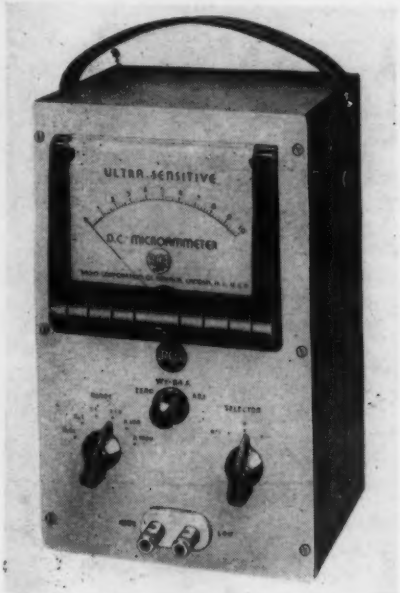

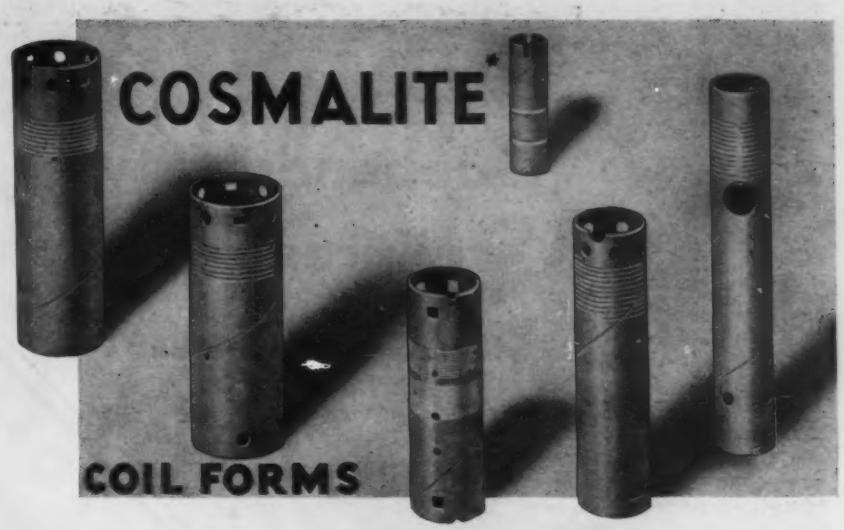

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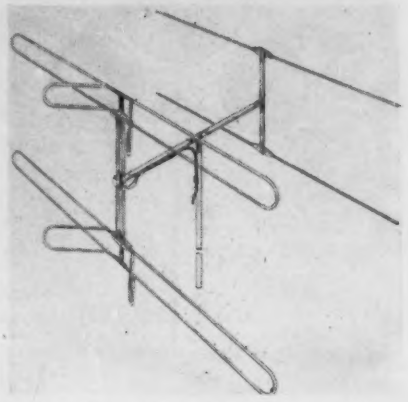
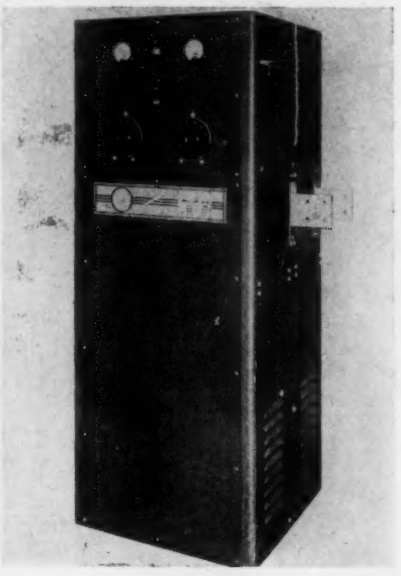


conversion kits has been assembled. In all there are 22 different types ranging from the single straight dipole to the double-stacked folded dipole with high-frequency lobes, as illustrated. The line covers the 44 to 216-mc range, channels 1 to 13 and f-m bands.

Tap Switch Rectifier

RICHARDSON-ALLEN CORP., 15 West 20th St., New York, N. Y., announces a new series of selenium



rectifiers with 36-position tap switch controls. The units are standard up to 27-kw capacity.

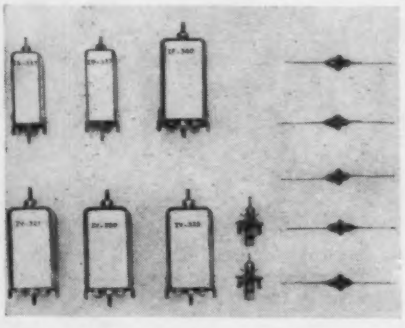
Auto-Radio Vibrators

AMERICAN TELEVISION & RADIO CO., 300 E. Fourth St., St. Paul 1, Minn., announces a complete line

of auto-radio vibrators designed for use in standard vibrator-operated auto and household radio receivers. The new line, featuring ceramic stack spacers, is covered in the recently released Vibrator Guide which is available free of charge.

Television Transformers

HILLBURN ELECTRONIC PRODUCTS CO., 1 Worth St., New York 13, N. Y. Series ZV video and sound trans-



formers are stagger tuned, have a 4-mc bandwidth, with sound rejection of 150 to 1 and adjacent channel rejection of 100 to 1.

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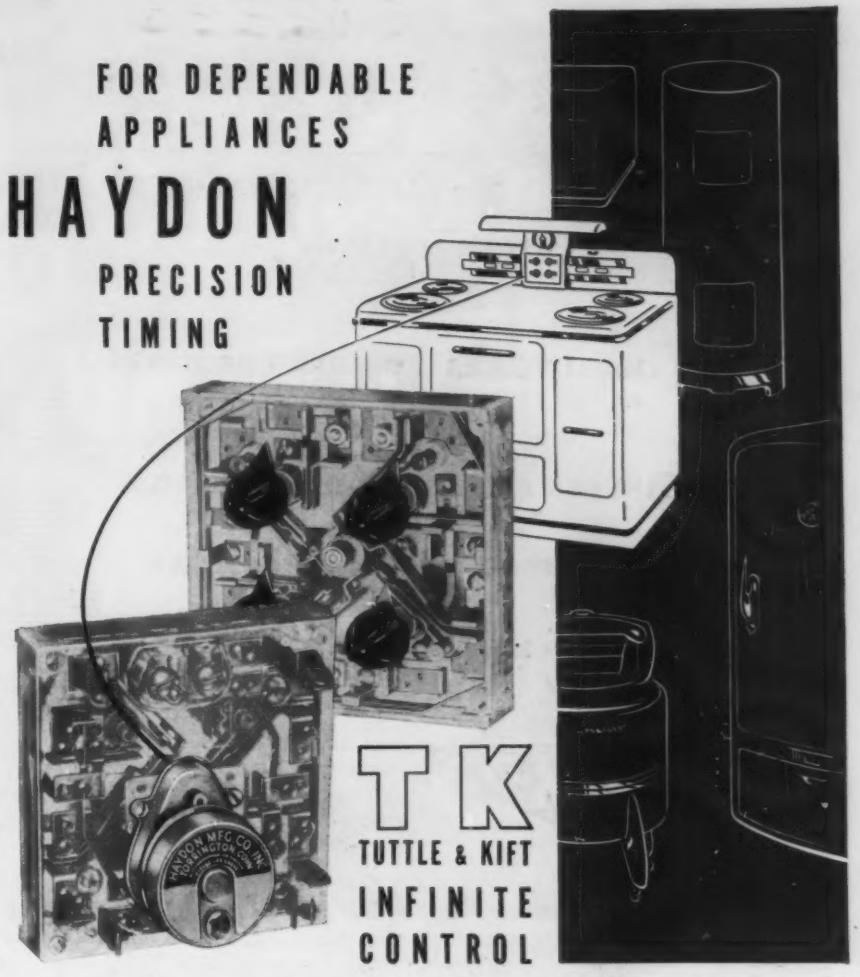

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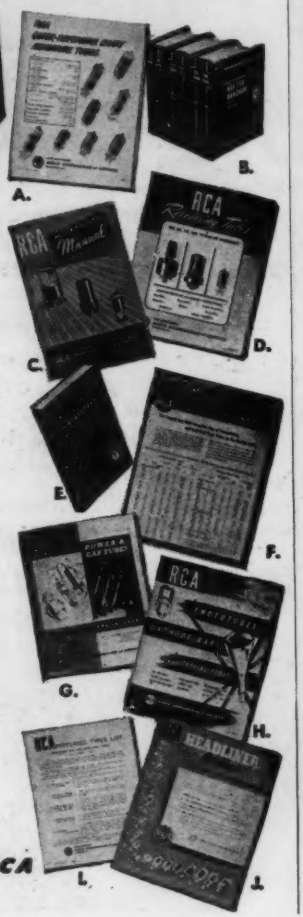

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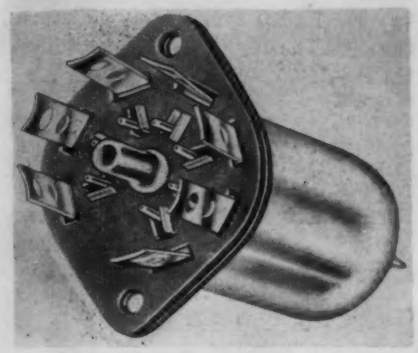

nance of critical dimensions and holding tension of the contact. It is available in 1-inch and 1⅛-inch mounting centers, plain or shielded, and in grounded types with seven or eight contacts.

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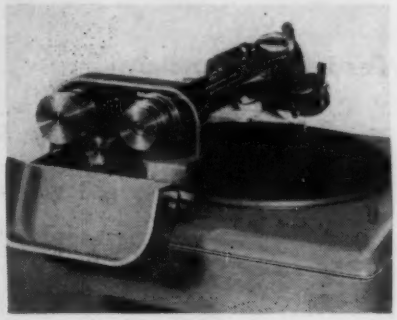
ROBINSON RECORDING LABORATORIES, 2022 Sansom St., Philadelphia 3, Pa., introduce the new lathe type recorder for professional work in radio stations and recording stu-



dios. Wow factor is reduced to 0.01 percent by use of a new belt drive and dynamically balanced components. The unit also features a ground thread feed screw which eliminates the feed screw pattern.

Loudspeaker

RADIO-MUSIC CORP., Port Chester, N. Y. The new Hyper-Mag loudspeaker features a parabolic projector and frequency range from 50

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A Complete Line of Vibrators . . . Designed for Use in Standard Vibrator-Operated Auto Radio Receivers. Built with Precision Construction, *featuring Ceramic Stack Spacers* for Longer Lasting Life.

New 34 page VIBRATOR GUIDE FREE

New Models

ATR

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For Inverting D. C. to A. C. . . . Specially Designed for operating A. C. Radios, Television Sets, Amplifiers, Address Systems, and Radio Test Equipment from D. C. Voltages in Vehicles, Ships, Trains, Planes and in D.C. Districts.

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✓ NEW DESIGNS
✓ NEW LITERATURE
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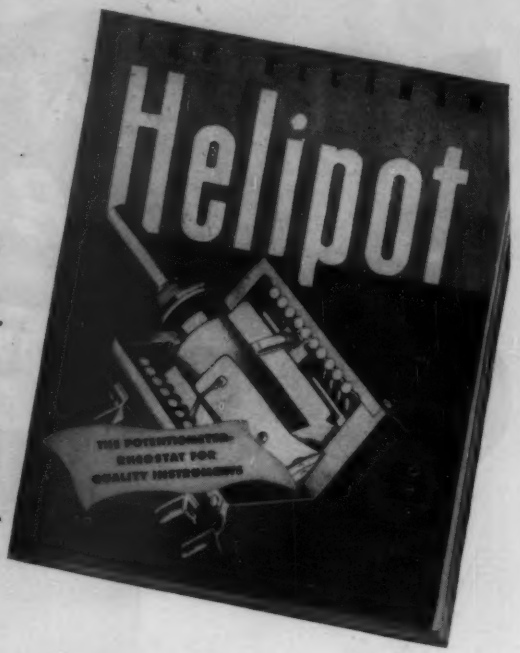
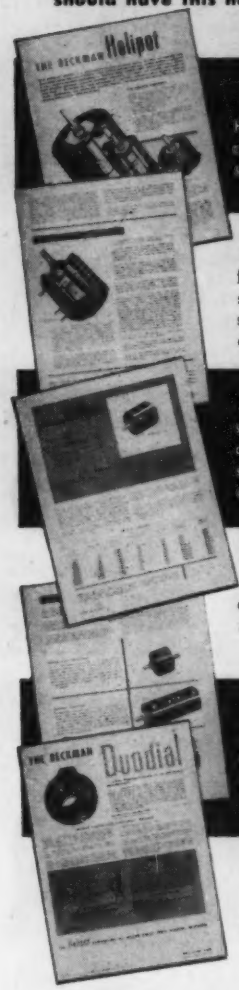
AMERICAN TELEVISION & RADIO CO.
Quality Products Since 1931
SAINT PAUL 1, MINNESOTA—U. S. A.

Do you have This Helpful Helipot and Duodial Catalog?



Do you have complete data on the revolutionary new HELIPOT—the helical potentiometer-rheostat that provides many times greater control accuracy at no increase in panel space?... or on the equally unique DUODIAL that greatly simplifies turns-indicating applications? If you are designing or manufacturing any type of precision electronic equipment, you should have this helpful catalog in your reference files...



It Explains – the unique helical principle of the HELIPOT that compacts almost four feet of precision slide wire into a case only 1½ inches in diameter—over thirty one feet of precision slide wire into a case only 3½ inches in diameter!

It Details – the precision construction features found in the HELIPOT... the centerless ground and polished stainless steel shafts—the *double* bearings that maintain rigid shaft alignment—the positive sliding contact assembly—and many other unique features.

It Illustrates – describes and gives full dimensional and electrical data on the many types of HELIPOTS that are available from 3 turns 1" diameter sizes to 40 turns, 3" diameter sizes... 5 ohms to 500,000 ohms 3 watts to 20 watts. Also Dual and Drum Potentiometers.

It Describes – and illustrates the various special HELIPOT designs available—double shaft extensions, multiple assemblies, integral dual units, etc.

It Gives – full details on the DUODIAL—the new type turns-indicating dial that is ideal for use with the HELIPOT as well as with many other multiple-turn devices, both electrical and mechanical.

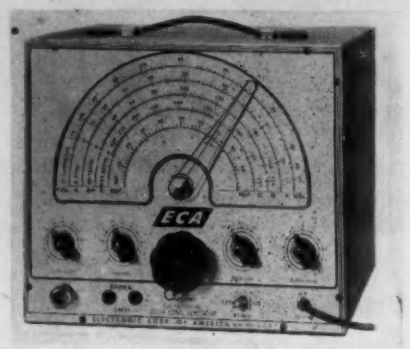
If you use precision electronic components in your equipment and do not have a copy of this helpful Helipot Bulletin in your files, write today for your free copy.

THE Helipot CORPORATION, 1011 MISSION ST. SOUTH PASADENA 2, CALIF.

to over 10,000 cycles at low distortion. It is fully described in Bulletin HS-1.

Sweep Signal Generator

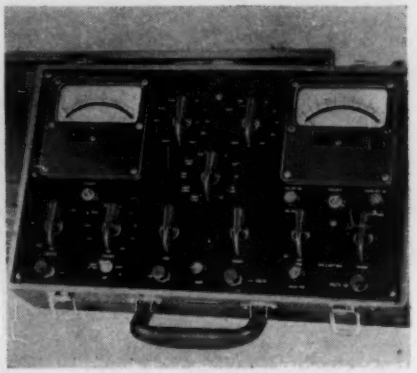
ELECTRONIC CORP. OF AMERICA, 170 53rd St., Brooklyn 32, N. Y. New York, N. Y. An f-m and television signal generator featuring a sweep



width of 500 kc to approximately 10 mc with a 60-cycle horizontal sweep output, has a frequency range of 2 to 227 mc in three bands. Price is $34.95 complete.

Testing Multimeter

M. C. MILLER, 1142 Emerson Ave., W. Englewood, N. J. Model No. 5 is a multi-combination meter designed for electrolysis and corro-



sion investigations and cathodic protection testing both in field and laboratory. It provides all of the instrumentation required to cover the wide range of d-c current and potential measurements necessary in this field. The unit weighs about 23 pounds.

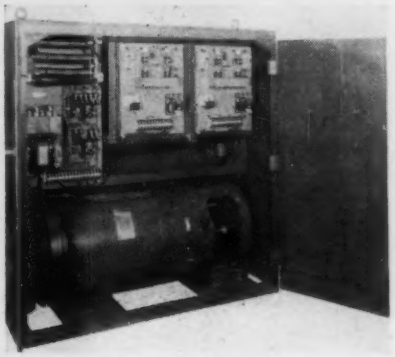
Synchronizing Generator

ALLEN B. DU MONT LABORATORIES, INC., 42 Harding Ave., Clifton, N. J. Type 5030-A is a portable

television synchronizing generator useful for testing transmitters, experimental development and laboratory work. Only a-c power is required. Half-line driving pulses are provided for using differential delay techniques necessary for long camera cable hookups. The instrument weighs about 50 lb.

Synchronizing Speed Control

RELIANCE ELECTRIC & ENGINEERING CO., Cleveland, Ohio. The Short Stroke Dancer Roll Control is designed for synchronizing the speed



of independently driven machines used in paper finishing, rubber extrusion and other continuous process operations. The unit has been designed for 230 volt d-c service and a maximum current of 2 amperes.

Audio Amplifiers

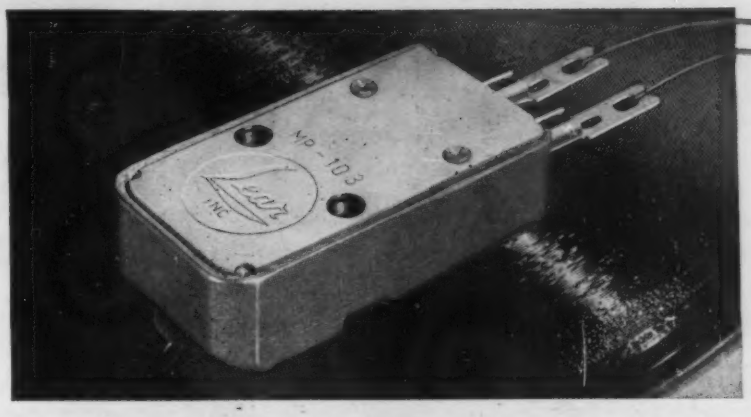
SETCHELL CARLSON, INC., 2233 University Ave., Saint Paul 4, Minnesota. Model PA722 master amplifier and model B422 booster are illustrated. As many as ten boosters can be used, each one providing its own 25-watt output with separate gain control. The booster units are

The Sweetest Music this Side of Heaven...

from this NEW, IMPROVED

Lear MAGNETIC PHONO PICK-UP

HIGH FIDELITY



$ Profit and Exquisite Record Reproduction...

JOBBERS ... SERVICEMEN ... turn service calls into profitable sales with ease. This new LEAR Reluctance Pick-Up transforms "flat" old-fashioned sound into full-toned modern reproduction!

This new, improved High-Fidelity Reluctance Pick-Up is LEAR engineered to excel in quality of performance . . . and priced for your profit. Replaces millions of old style crystal pick-ups now in use! Jewel stylus eliminates needle changing — holds surface noise to a bare minimum. It performs a miracle of modernization — assures full tonal beauty of sound wherever installed.

List this "hot" seller in your catalog! Service men who feature the new LEAR Magnetic Pick-up will pick up extra profits every day! Cash-in now–write for complete discount price list *today!*

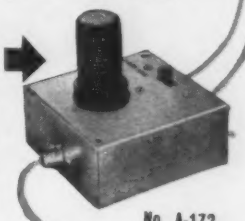
To complete your LEAR Sound Service:

New, Improved LEAR PRE-AMPLIFIER, List Price—$9.90

To provide additional amplification with use of MP-103 LEAR Magnetic Pick-up. Can be connected directly to old crystal cartridge input. High voltage and filament wires provided for connection into existing equipment. Two-position switch permits high-fidelity response to finest quality recordings.

No. PA-103 (not shown here)—LEAR Tone Arm Assembly with MP-103 Magnetic Variable Reluctance Pick-Up Cartridge, List Price $15.50.

Designed for high-fidelity reproduction of 10" and 12" recordings. Spring counter-balance provides "feather touch" operation—only 17 grams stylus pressure on record. This reduces record wear to a minimum. Handsomely finished in brown metallic.



No. A-172

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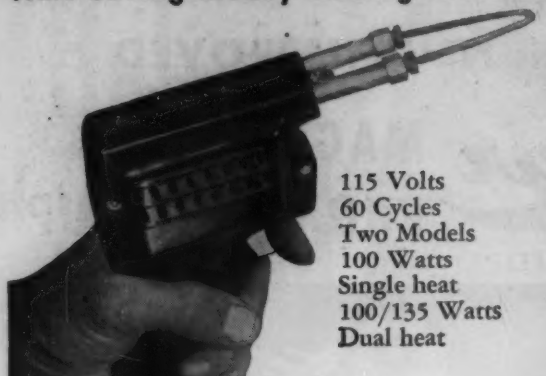
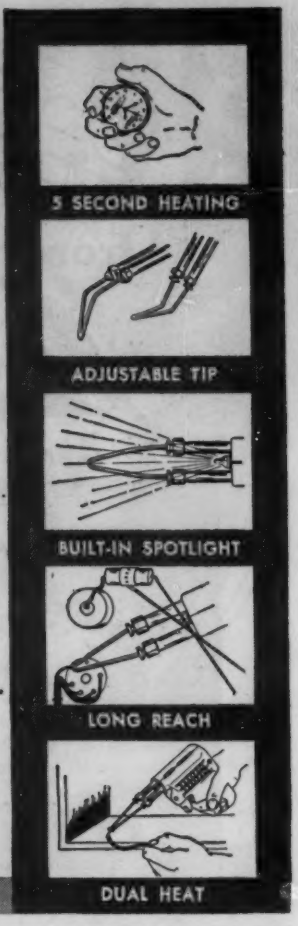
SOLDERING GUN
Time Saving-Money Making Features



115 Volts
60 Cycles
Two Models
100 Watts
Single heat
100/135 Watts
Dual heat



See your radio parts distributor or electrical wholesaler. Or write direct for bulletin.

WELLER Mfg. Co.
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DETECTING A SMALL LEAK STOPPED A FLOOD IN HOLLAND

WHAT ARE LEAKS COSTING YOU IN PRODUCT PERFORMANCE OR EQUIPMENT FAILURE?

VEECO
MASS SPECTROMETER

LEAK DETECTOR
Makes BIG profits by finding small leaks

The Veeco finds small holes, locates them accurately. Highly sensitive vacuum and pressure testing finds small leaks in industrial equipment and finished products. Quick, dependable. Now successfully used for testing: electronic tubes, glass-to-metal seals, hermetically sealed systems, condensers, and scores of other products. Simple operation. Literature LD-35 upon request.

Veeco LEAK DETECTOR

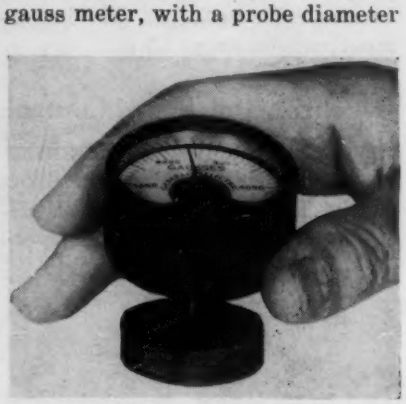
*Manufactured under license of the University of Minnesota

VACUUM-ELECTRONIC ENGINEERING CO.
316 37th STREET • BROOKLYN 32, N. Y.

mechanically attached to the base of the amplifier by means of concealed tiebolts.

Gauss Meter

GENERAL ELECTRIC Co., Schenectady 5, N. Y. The new direct-reading gauss meter, with a probe diameter



of 0.052 inch, permits measurement of flux in small-gap magnets of standard or irregular shape. Also available is a triple kit combining three meters of different ratings in a single carrying case. Ask for bulletin GEC-238.

Literature

Laboratory Instruments. Technology Instrument Corp., 1058 Main St., Waltham 54, Mass. A new bulletin describes and illustrates types 410-A r-f oscillator and 310-A Z-Angle meter. Specifications and simplified circuit diagrams are included.

Snap-Action Switches. Micro Switch, Freeport, Ill. Microtips, the first issue of a new publication, promises to tell in following

issues how plant engineers and electrical maintenance men are using snap-action switches. The pamphlet is punched for a standard 3-ring binder so that each copy may be filed for ready reference.

Magnetic Iron Powders. C. K. Williams & Co., Metallurgical and Electronic Division, 2001 Lynch St., East St. Louis, Ill., offers a brochure filled with data and a price list on a variety of IRN magnetic iron powders. Also available is the condensation of an article on the effective permeability of h-f iron cores.

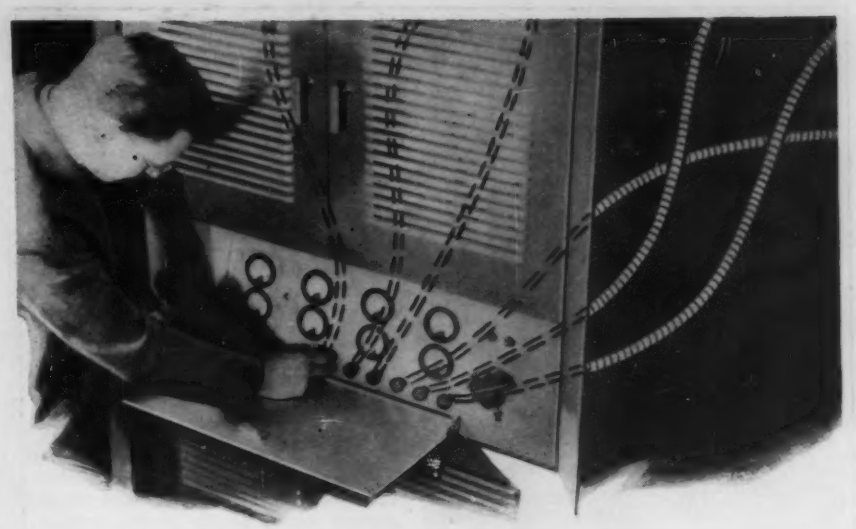
Terminals. Shakeproof Inc., Division of Illinois Tool Works, 2501 North Keeler Ave., Chicago 39, Ill. Catalog A-S-51 contains dimensional data and general information to simplify selection and specification of proper wiring terminals for designers and draftsmen of radios and electrical devices. Working drawings of each part are included.

Crystal Units. Standard Piezo Co., P. O. Box 164, Carlisle, Pa. Eleven types of crystal units are pictured in a 4-page folder. Chief features are outlined and ordering information is given.

Miniature Speed Changers. Metron Instrument Co., 432 Lincoln St., Denver 9, Colorado. Bulletin No. 100 shows three types of miniature speed changers with a table giving all of the standard integral ratios. Power is transmitted either way for ratios below 230 to 1.

Coaxial Frequency Meter. Frequency Standards Corp., 237 Lafayette St., New York 12, N. Y. A loose-leaf perforated folder points out the prominent features of model 315A frequency meter which covers the 300 to 1500-mc range in four overlapping bands.

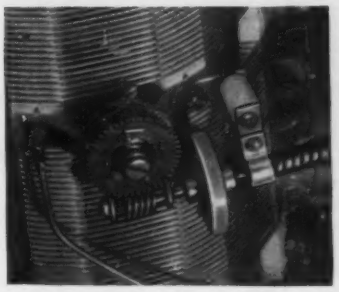
Portable Wire Recorder. Precision Audio Products, Inc., 1133 Broadway, New York 10, N. Y. Two sides of a single sheet show



FLEXIBLE SHAFT CONTROL
IS AS GOOD AS YOU REQUIRE

You can get any degree of fidelity and sensitivity you need with S. S. White remote control flexible shafts.

Bear in mind, these shafts were developed specifically for control service. They have the necessary physical properties to provide a quality of control that satisfies the requirements of most applications. Its simply a matter of correct shaft selection and application.



Close-up of flexible shaft connection to a variable resistor through simple worm gearing. With arrangements like this you can get smooth, accurate fingertip control.

Where vernier accuracy is essential, it is readily obtained by connecting the shaft to control and controlled members through simple gearing.

GET FULL DETAILS IN THIS 260-PAGE FLEXIBLE SHAFT HANDBOOK

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FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
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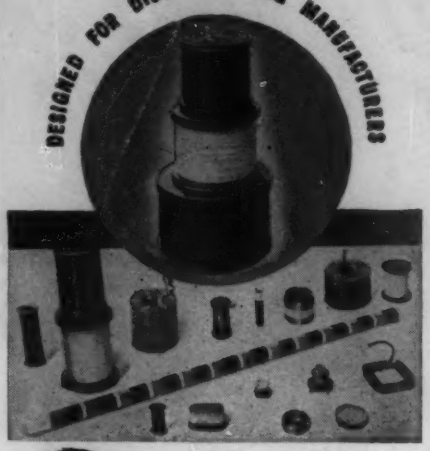

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ENAMELED MAGNET WIRE

A product, resulting from many years of research in the field of fine wire manufacture, that meets the most rigid requirements of radio and ignition coils.

A new coating method gives a smooth, permanently - adherent enameling, and mercury-process tests guarantee perfect uniformity. Great flexibility and tensile strength assure perfect laying, even at high winding speeds. If you want reduction in coil dimensions without sacrificing electrical values, or seek a uniform, leakproof wire that will deliver extra years of service, this Hudson Wire product is the answer.

QUALITY · UNIFORMITY · SERVICE

Also manufacturers of high grade cotton and silk covered wires, cotton and silk coverings over enamel coated wires, and all constructions of Litz wires. A variety of coverings made to customers' specifications, or to requirements determined by our engineers. Complete design and engineering facilities are at your disposal; details and quotations on request.

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Studio Quality AMPLIFIERS

WITH CUSTOM-BUILT FEATURES

Design of Bardwell & McAlister's New Commercial Amplifiers embodies the principles which have been proven in custom-built units developed in the Motion Picture Industry, where quality is requisite. Fully licensed.

12w. models operate up to 8 indoor speakers, effectively cover outdoor audience of 2500.

25w. models operate up to 16 indoor speakers, effectively cover outdoor audience of 8000.

Designed & fabricated by manufacturers of high quality Sound & Recording Equipment for the Motion Picture Indusfry. Union made.

2 to 4 high gain input channels and 2 to 4 high or low gain radio or phonograph input channels.

With or without professional "T" type bass and treble equalizers.

High fidelity reproduction at any setting of volume controls up to full rated output with less than 4% distortion.

Frequency response flat within ½ db from 50 to 10,000 cycles.

Output impedances 500, 250, 16 & 8 ohms. Overall gain 105 db. Hum level 85 db below full output.

Write today for informative catalog & Technical data.
Dealer inquiries invited.

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ELECTRONIC DIVISION
BARDWELL & McALISTER, INC.
BOX 1310, HOLLYWOOD 28, CALIFORNIA

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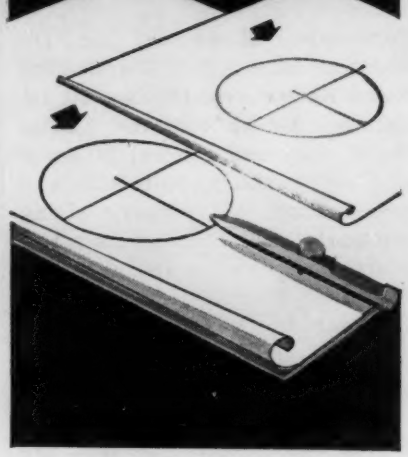

• The renown of Imperial as the finest in Tracing Cloth goes back well over half a century. Draftsmen all over the world prefer it for the uniformity of its high transparency and ink-taking surface and the superb quality of its cloth foundation.

Imperial takes erasures readily, without damage. It gives sharp contrasting prints of even the finest lines. Drawings made on Imperial over fifty years ago are still as good as ever, neither brittle nor opaque.

If you like a duller surface, for clear, hard pencil lines, try Imperial Pencil Tracing Cloth. It is good for ink as well.

IMPERIAL TRACING CLOTH

SOLD BY LEADING STATIONERY AND DRAWING MATERIAL DEALERS EVERYWHERE

the outstanding features and technical specifications of the Wiremaster, a portable wire recorder. Frequency range is from 40 to 10,000 cps and the unit has separate listening and recording volume controls.

Laboratory Monitor. Tracerlab, Inc., 55 Oliver St., Boston 10, Mass. Model SU-3 was developed for use as a routine contamination monitor in radioactivity laboratories. Bulletin No. 9 gives a 12-page description of the instrument complete with diagrams.

Vacuum Melting. National Research Corp., 70 Memorial Drive, Cambridge 42, Mass. The new brochure on high-vacuum furnaces outlines equipment for metallurgical melting and casting in the micron pressure range. Components are sketched and described, and a bibliography is included.

Sound Reproduction. Terminal Radio Corp., 85 Cortlandt St., New York 7, N. Y. Amplifiers, microphones, loudspeakers, and wire recording equipment are described and illustrated in an eight-page catalog. Prices for individual items are listed.

Receiving Tube Reference. Radio Corp. of America, Harrison, N. J. The latest edition, form 1275-D, is a compact and informative booklet on receiving tubes for television, f-m and standard broadcast. Price is ten cents.

Sound Recorder. Sound Apparatus Co., 233 Broadway, New York 7, N. Y. Literature is now available on the newly designed model HPL high speed recorder and requests for the bulletin "Sound Advances" will be promptly filled.

Portable C-R Scope. Tektronix, Inc., 1516 S. E. Seventh Ave., Portland 14, Oregon. A recent 4-page folder on the type 511 cathode-ray oscilloscope gives a general description of the portable unit along with a thorough treatment of its vertical and horizontal de-

NEW DEVELOPMENTS IN VACUUM CAPACITORS

By

United Electronics Company

When the older types of vacuum condensers were designed, the sole conception of advantage was to attain a voltage breakdown characteristic higher than could be accomplished with condensers of the same physical size with air or other substance as dielectric.

The limitations of the old types of vacuum capacitors resulted principally from high R.F. losses and a high temperature co-efficient. This caused considerable capacitance drift, and the added heat losses in the glass envelope led to external voltage breakdown or internal breakdown due to the liberation of gas. Actual seal puncture in these early type vacuum capacitors was also a frequent cause of failure. Extraneous inductance was caused by the use of conventional ferrous metal rod seals and copper strand leads soldered to the terminal caps, in the old type of construction. The higher the frequency and R.F. power, the more these limitations were accentuated.

Outstanding features of UNITED vacuum capacitors are the employment of large copper elements and large periphery glass to copper seals, and end caps as illustrated. This construction results in a low temperature co-efficient, low R.F. losses and low inherent inductance. End flanges as well as terminals are gold plated to prevent corrosion.

Vacuum Capacitor Cap—50/60/35

Type designations of UNITED vacuum capacitors symbolize their capacitance ratings and their maximum current and voltage ratings—thus:

C	A	P
=	=	=
Capacitance	Amperes	Potential
(50 uuf)	(60)	(35 KV)

The numerals are significant as shown in direct relation to the prefix letters.

The 5 types listed below are designed for peak working voltage of 35 KV.

PRESENT SIZES AND RATINGS

Type	Capacitance uuf	Maximum Current	Peak R. F. Voltage	Overall Dimensions Length	Width
CAP-25/30/35	25	30 amps.	35 KV	6½"	2½"
CAP-50/60/35	50	60 amps.	35 KV	"	"
CAP-75/60/35	75	60 amps.	35 KV	"	"
CAP-100/60/35	100	60 amps.	35 KV	"	"
CAP-250/60/35	250	60 amps.	35KV	"	3"

Contact terminal diameter 13/16 ; length 23/32 ; standard capacitance tolerance ± 2%; can be furnished in precision tolerance ± 1% at increased cost.

UNITED vacuum capacitors have OFHC copper elements for high RF conductivity. Low temperature coefficients and noninductive characteristics make these units desirable for high power, high frequency applications where space, minimum drift and freedom from breakdown are important considerations.

Write for a copy of our latest catalog on Transmitting Tubes featuring the Patented Isolated Getter Trap and Complete data on Vacuum Capacitors.

UNITED ELECTRONICS CO.

42 Spring Street

Newark 2, New Jersey

flection systems. Characteristics and other pertinent data are covered.

Components. Hugh H. Eby, Inc., 4741 Stenton Ave., Philadelphia, Pa., announces publication of a 48-page loose-leaf catalog showing a complete line of components. Pertinent dimensions of sockets, plugs, connectors, jacks, terminal strips and a wide variety of binding posts in many models and sizes are given.

Microwave Supplies. The Waveguide Mfg. & Equipment Co., Inc., 125 E. 23rd St., New York 10, N. Y. A recently issued catalog illustrates and describes a variety of microwave test equipment, assemblies and components.

Service Manual. Clarostat Mfg. Co., Inc., 130 Clinton St., Brooklyn 2, N. Y. The new 127-page manual is a compilation of all standard type radios in current use, based on a survey by leading compilers of service data. Price is 50 cents per copy.

Precision Switches. Micro Switch Corp., P. O. Box 561, Freeport, Ill. Temporary data sheet 41 gives characteristics, diagrams and prices of skeleton switches. Also available is a loose-leaf descriptive sheet showing a switch in actual operation.

Electronic Timers. Radio Corp. of America, Harrison, N. J. Application Note AN-131 describes the use of type 2D21 or 2050 thyratrons in electronic timer circuits.

Television Antenna System. Workshop Associates, Inc., 66 Needham St., Newton Highlands 61, Mass. Television reception by means of multiple antennas and a coaxial selector switch is the latest practical slant on a difficult problem. Literature is now available.

Cathode-Ray Equipment. Allen B. DuMont Laboratories, Inc., Clifton, N. J. The Oscillographer is a bi-monthly loose-leaf perforated publication with information on different types of c-r tubes, polar-

Designed for M Application

THE NO. 92105
SSSR
Single Sideband Selector

We announce the No. 92105 Single Sideband Selector, see April QST for technical details, which permits single sideband selection with your present receiver! Produced in co-operation and under exclusive U.S. patent license (2,364,863 and others) with the J.L.A. McLaughlin Research Laboratories.

JAMES MILLEN MFG. CO., INC.
MAIN OFFICE AND FACTORY
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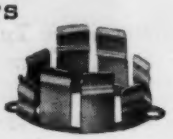
If you need Radio Parts...

in quantities suitable to Volume Production...it may pay you to call upon the Design Engineers of United-Carr and its

subsidiaries. They have helped many manufacturers



★ CUT COSTS
★ SPEED PRODUCTION
★ TURN OUT FINER FINISHED PRODUCTS

UNITED-CARR FASTENER Corp.
CAMBRIDGE 42, MASSACHUSETTS
MAKERS OF DOT FASTENERS

FASTER, SIMPLER

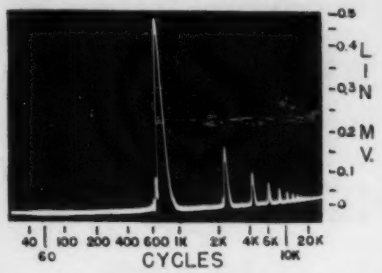
AUDIO ANALYSIS

with Model AP-1

PANORAMIC SONIC ANALYZER

Reduce time, complexity and cost of making audio measurements with the unusual advantages offered by the Panoramic Sonic Analyzer. By resolving a complex audio wave into a spectrograph showing the frequency distribution and voltage amplitude of the components, Model AP-1 . . .

• Eliminates slow point-by-point frequency checks • Provides a quick overall view of the audio spectrum • Enables determination of changes in waveform content while parameters are varied • Furnishes simple presentations for production line testing.



Panoramic Sonic Spectrograph of 750 cps square wave.

Use Model AP-1 for analyzing . . .
• Harmonics • Intermodulation • Vibration • Noise • Acoustics • Materials

Features . . . Continuous scanning from 40-20,000 cps in one second • Wide input voltage range • Linear and log voltage scale • Closely logarithmic frequency scale • Built-in voltage and frequency calibrator • Simple operation.

WRITE for detailed specs, price and delivery.

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Exclusive Canadian Representative: Canadian Marconi, Ltd.

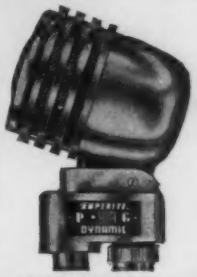
AMPERITE MICROPHONES

The ultimate in microphone quality, the new Amperite Velocity has proven in actual practice to give the highest type of reproduction in Broadcasting, Recording, and Public Address.

The major disadvantage of pre-war velocities has been eliminated—namely "boominess" on close talking.

- *Shout* right into the new *Amperite Velocity*—or *stand 2 feet away*—the quality of reproduction is always excellent.
- *Harmonic distortion is less than 1%* (Note: best studio diaphragm mike is 500% higher).
- *Practically no angle discrimination . . . 120° front and back.* (Best studio diaphragm microphones—discrimination 800% higher).
- One Amperite Velocity Microphone will pick up an entire symphony orchestra.

AMPERITE
Velocity Microphones
for Public Address
Models RBHG, RBLG
List $42.00



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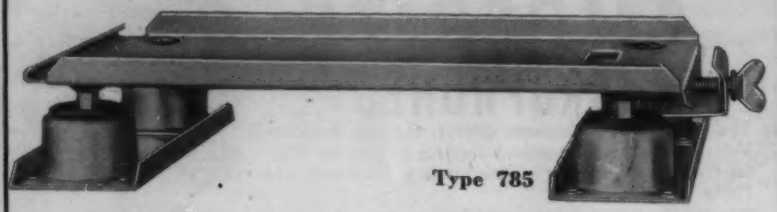

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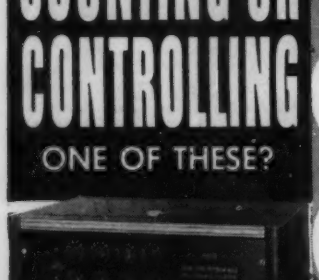

QUANTITY—Pills, buttons, bottle caps, hardware, etc., can be counted and batched in precise predetermined quantities at speeds up to 15,000 per minute. Important savings in labor and overages are assured by the speed and accuracy of the Potter Electronic Counter. Count Detectors for any product are available.

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coordinate indicators, h-v power supplies, oscillographs and like equipment.

Speakers. Altec Lansing Corp., 250 W. 57th St., New York 19, N. Y., gives response curves and data on four of its outstanding speaker designs in a recently issued 6-page folder.

Synthetic Sapphire. Sapphire Products Division, Elgin National Watch Co., Aurora, Ill. An 8-page pamphlet explains the uses and properties of synthetic sapphire in industry.

Wire Recorder. Electronic Sound Engineering Co., 4344 Armitage Ave., Chicago 39, Ill., has a brochure describing the Polyphonic Sound recorder model PS179. Frequency range of the system is 30 to 15,000 cycles.

Metal-Backed Screen. General Electric Co., Syracuse, N. Y. A new 10-inch metal-backed direct-view television picture tube that gives better pictures at more normal ambient light levels has recently been announced.

Communications Equipment. Browning Laboratories, Inc., Winchester, Mass. A 4-page brochure describes the line of tuners, frequency meters, capacitance alarm, and other devices.

Instrument Catalog. Electro-Tech Equipment Co., 117 Lafayette St., New York 13, N. Y. Catalog 48 illustrates and describes a line of instruments of many manufacturers from A battery eliminators to Wheatstone bridges in 65 pages.

Carbon-Graphite. Stackpole Carbon Co., St. Marys, Pa. Tube anodes, battery carbons, ground rods, electrical contacts, and spectrographite are among the many carbon products discussed in a new 44-page booklet.

Measuring Frequency. General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass. Volume XXII No. 9 of the Experimenter

describes the type 1141-A audio-frequency meter as well as the 1231-B amplifier and null detector. Illustrations, schematic diagrams and characteristic curves of both units are also shown.

Miniature Iron. Television, Inc., New Rochelle, N. Y. The Soldetron miniature soldering copper operates from a storage battery or 6-volt transformer and is described in a sheet recently issued.

Plastic Bulletin. Fabri-Form Co., 100 Seneca St., Byesville, Ohio. Some of the newest ways to use plastics are shown in a new 12-page bulletin. Over fifty drawings and photographs illustrate detailed parts in a manner that is simple to the layman.

H-F Conductor. Titeflex, Inc., 591 Frelinghuysen Ave., Newark 5, N. J. Water-cooled, flexible leads for use in conducting high-frequency currents are described in a folder just issued. List prices are included.

Timing Motors and Devices. Haydon Mfg. Co., Torrington, Conn. Of value to engineers and designers is the 16-page, 2-color catalog No. 320 on synchronous timing motors, timing devices and clock movements.

Miniature Tubes. Tung-Sol Lamp Works Inc., Newark 4, N. J. Actual sizes, advantages and applications of a line of miniature electron tubes are discussed in a six-page pamphlet.

Molded Metal Products. Keystone Carbon Co., 1935 State St., Saint Marys, Pa. A four-page circular covers powder metallurgy parts, motor and generator brushes, and negative temperature coefficient resistance units. Various types of each line are illustrated.

Radio and Recorder Catalog. Hoffman Radio Corp., Los Angeles, Calif., has published a 16-page catalog of its 1948 line. The brochure, specially featuring the

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- Research
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STEEL When a steel company engineer was presented with a problem of testing steel with an application of variable frequency, an oscillator output impedance as low as 0.01 ohms was required over a wide Frequency range.

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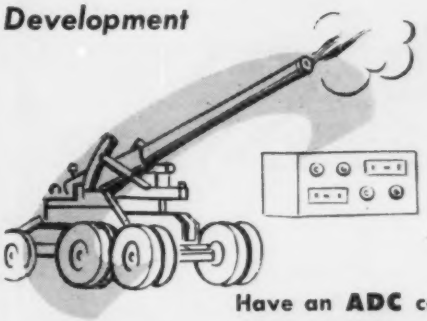

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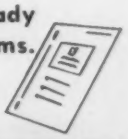

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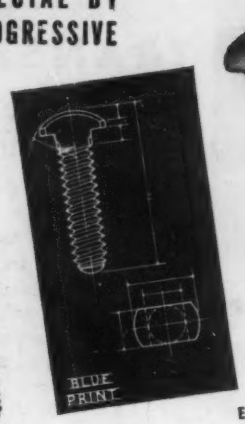

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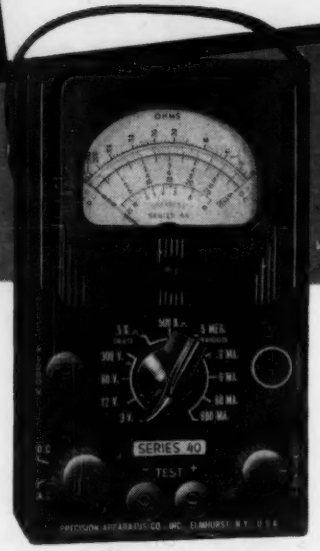

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Pins and Leads. The Bead Chain Mfg. Co., Mountain Grove and State Streets, Bridgeport 5, Conn. Multiswage contact pins are constructed with a hole through the entire length to facilitate threading lead wires. The contact pins are used for radio tubes, panel-mounted terminals, jacks, and leads for miniature and other radio tubes.

Insulating Material. General Ceramics and Steatite Corp., Keasbey, N. J. Catalog 3000 shows various methods of producing steatite insulators. Different types and shapes are discussed with mechanical drawings given throughout.

Test Instruments. General Electronic Distributing Co., 98 Park Place, New York 7, N. Y. Several models of tube and set testers, volt-ohm-milliammeters, signal generators and tracers are described in an 8-page catalog. Specifications and price of each are given.

Phase-Shift Modulator. Radio Engineering Laboratories, Inc., 35-54 36th St., Long Island City 1, N. Y. Bulletin 5030 contains a description of characteristics, functions and technical specifications of the Serrasoid phase-shift modulator for f-m broadcasting.

Metered Variable Transformers. Standard Electrical Products Co., 400 Linden Ave., Dayton 3, Ohio. A four-page folder describes a new line of Adjust-A-Volt metered variable transformers, including isolated primary transformers with secondary voltages of 0 to 140 volts and autotransformers with the same output voltage.

Radio Service Encyclopedia. P. R. Mallory & Co., Inc., Indianapolis, Ind. The sixth edition of this reference book of useful service information contains 25 percent more listings than the fifth edi-

Sensitive **MULTIPLE ARM RELAYS**

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SIGNAL ENGINEERING offers a new series of small, rugged, general purpose Multiple Arm Relays adaptable to a wide variety of circuit arrangements.

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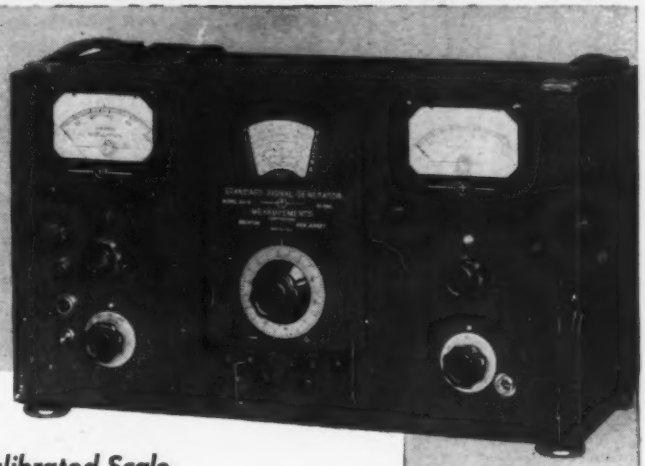
STANDARD SIGNAL GENERATOR

MODEL 65-B

RANGE 75 KC to 30 MC



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MODULATION: From zero to 100%. 400 cycles, 1000 cycles and provision for external modulation. Built-in, low distortion modulating amplifier.
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DIMENSIONS: 11" high, 20" long, 10¼" deep, overall.
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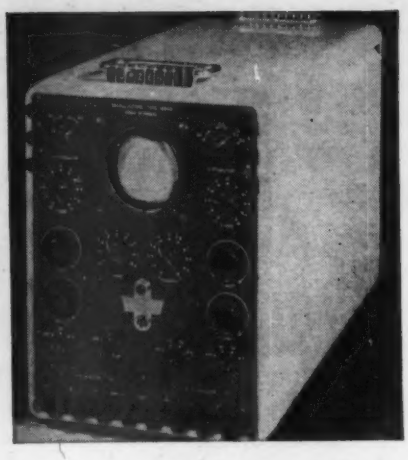

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tion. A reference to Rider's Manual, volume and page number for each receiver, is shown. The encyclopedia is available at a net price of $2.00.

Revolving Antenna. Kings Electronics, 372 Classon Ave., Brooklyn 5, N. Y. A looseleaf-perforated folder gives the chief features and prices of several models of Roto Beam dipole rotating antennas for the elimination of ghosts and weak stations in television reception. Typical installations are shown.

Loud Speakers. Magnavox Co., Fort Wayne 4, Ind., has just issued a complete compilation of all pertinent engineering data with illustrations and dimensional information covering all current models of loudspeakers available to manufacturers.

Oscillograph Photography. Fairchild Camera and Instrument Corp., 88–06 Van Wyck Blvd., Jamaica 1, N. Y. The Oscillo-Record camera is designed for recording cathode-ray oscillograph images. A complete description along with specifications, accessories and catalog listings can be found in a recent 12-page booklet.

Connecting Devices. Howard B. Jones Div., 2460 W. George St., Chicago 18, Ill. Catalog 16 lists various types of electrical connecting devices together with photographs and sketches of the products to facilitate ordering.

Resistors. Precision Resistor Co., 336 Badger Ave., Newark 8, N. J., has issued a 4-page bulletin setting forth a variety of inductive and noninductive resistors. The latest catalog covering wirewound resistors in full detail may be had on request.

Remote Control. Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J. An 8-page bulletin 711–21 illustrates a remote torque control system. The control comprises a transmitting synchro, amplifier, and the torque unit.

rights and privileges of the society.

(4) *Associates:*—Any person interested in the objectives of the audio engineering society shall be eligible to election to associate membership in the society and shall upon election become entitled to all the rights and privileges of the society, except the right to vote or to hold office or chairmanship of standing committees. However, associates of record at the institution of the society shall have the right to vote as long as membership shall be continuous and maintained.

(5) *Student Members:*—A student interested in audio engineering and enrolled in a recognized school, college or university may apply for student membership in the society. Upon election, however, a student member shall not be eligible to vote or for membership on committees except in his local student chapter.

(6) *Sustaining Members:*—Any person, corporation or organization annually contributing substantially to the Society shall be eligible for election to sustaining membership in the society.

Regular meetings will be held on the second Tuesday of each month except during July and August, with an annual meeting each October. The annual dues shall be as follows: honorary member, none; fellow, $7.50; member, $7.50; associate member, $6.00; student, $3.00.

IRE Plans Group System

TWO TYPES of professional groups will soon be formed within the IRE: (1) vertical—illustrated by the broadcast engineering group and (2) horizontal—as in the audio, video and acoustic group. Each group will elect a chairman, vice-chairman and executive committee, to look after its own interests.

Other groups are anticipated to provide a further integration of the vastly expanded fields of communications and electronics into areas of special technical interests. An individual group can be instituted by petition from 25 or more members of the Institute. Each group may activate its own committees, special conferences, and meetings, and may expect to take charge of one or more programs at

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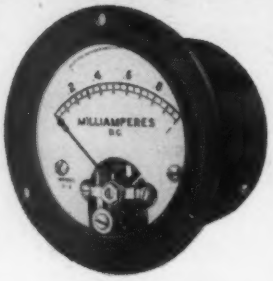

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Kotron's metallic rectifying elements are mounted in one plane. Plates cannot contribute heat to each other. Result—Cooler Operation . . . longer life . . . increased circuit efficiency. Wafer-thin Kotron saves space, mounts easier.

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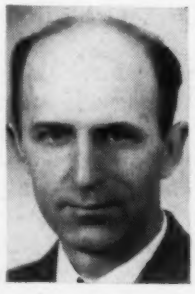
sessions of National and Regional conventions, as well as provide for limited distribution of papers of special interest. Correspondence regarding the formation of groups should be addressed to L. G. Cumming, technical secretary of the IRE, 1 East 79th St., New York City.

Coffin Awards Bestowed

SIX MEMBERS of General Electric's Electronics Department have received the Charles A. Coffin award, highest honor bestowed by the company, for outstanding work during 1946 and 1947 on transmitting and broadcasting developments. The recipients are as follows:

William F. Goetter, Ross A. Lash and Henry P. Thomas of the transmitter division at Syracuse, N. Y., for their efforts in the design and development of a new line of f-m broadcast transmitters.



W. F. Goetter

R. A. Lash

H. P. Thomas

R. B. Dome

R. P. Watson

K. C. DeWalt

Robert B. Dome of the receiver division at Syracuse, N. Y., in

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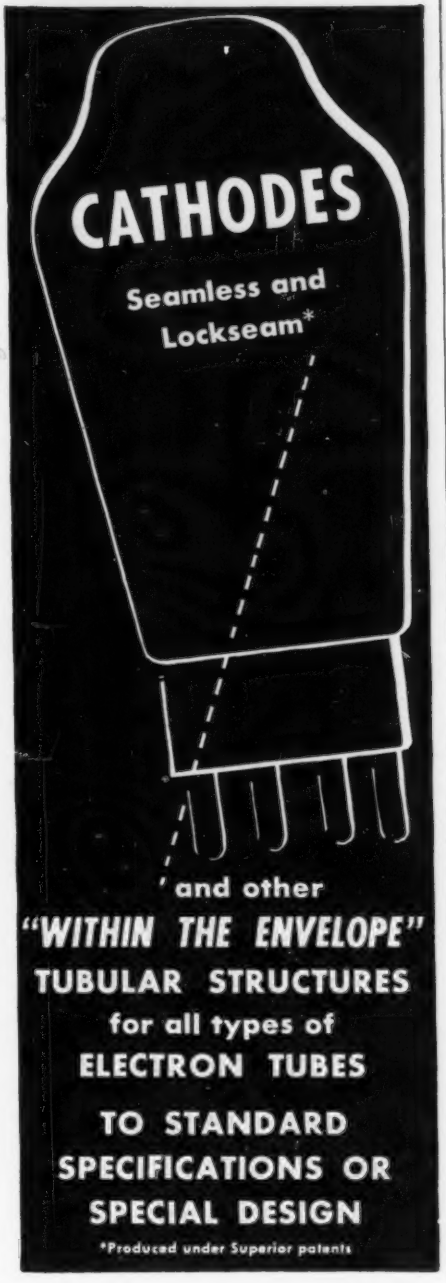

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ELECTRONICS DIVISION
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NORRISTOWN, PA.

recognition of his invention of a new circuit system for communications equipment.

Robert P. Watson and F. M. Bailey of the tube division at Schenectady, N. Y., a joint award for work in developing the phasitron.

Kenneth C. DeWalt of the tube division, for transmitter-tube production accomplishments, especially in connection with the Manhattan District.

Marine VHF Service

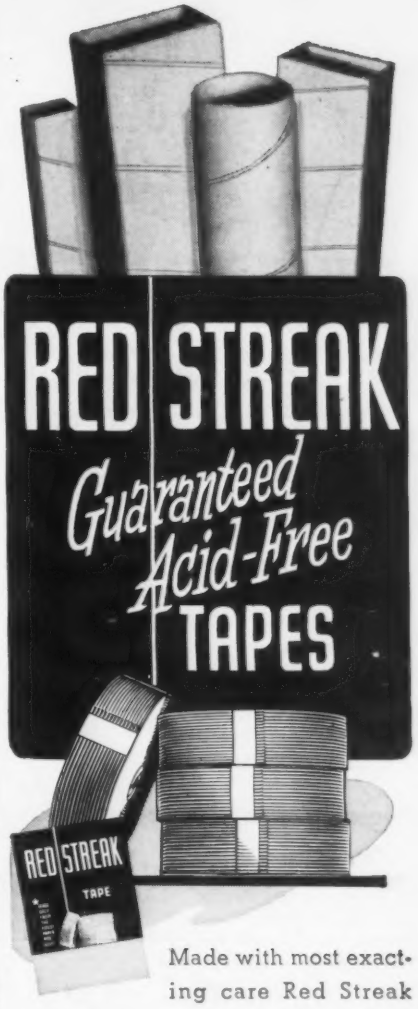
THE FCC has announced its decision to establish a vhf radiotelephone maritime mobile service on a regular basis for the operational and business needs of ships. In this connection, class 2 experimental applications have already been granted for certain land radiotelephone stations and associated stations aboard tugboats. These are of an interim character prior to the formulation of rules for the regular service. Further interim grants will be made to eligible applicants, but will not be for use on a common carrier basis. Common carrier experimentation can continue on the one duplex channel now being used.

New Technical Society

FORMATION of a new technical organization, the Standards Engineering Society, was recently announced. Its purpose is to remove barriers that tend to isolate various fields of engineering. Members may be any type of engineer—mechanical, industrial, electrical—so long as their work is concerned with standardization.

Stanley Zwerling of the Army-Navy Electronics and Electrical Standards Agency, Eatontown, N. J., was elected president, and serves on the steering committee along with Harold R. Terhune of RCA Victor, George Burnett of Sperry Gyroscope Co., P. K. McElroy of General Radio Co., and Karl Geiges of the Underwriters' Laboratories, Inc.

Due to present lack of office space, membership is now limited to the several thousand doing standards work in or near New York. A bulletin, to be published after each bi-monthly meeting, will be avail-



Made with most exacting care Red Streak Acid-Free tapes and gummed flat sheets are made to conform to the most critical specifications and are uniform throughout. Tests for free acids and alkalines are made by P H method. Available in materials and thicknesses below. Write for your Red Streak samples.

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Speeds Accurate Analysis of Audio Circuits! Simplifies Selection of Components! Saves Valuable Time!

Here's an instrument that will do most of the jobs usually assigned to a square wave generator costing about 10 times as much! The B&W Sine Wave Clipper provides a test signal particularly useful in examining the transient and frequency response of audio circuits. Designed to be driven by an audio oscillator, the clipper provides a clipped sine wave—hence the name "Sine Wave Clipper!" Used in engineering work, repair work, or with equipment under development, it will quickly pay for itself many times over.

Write for complete information

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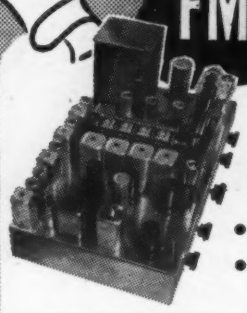
FM·AM TUNER



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- A. M. Up to 10,000 cycles without loss.
- F. M. High Fidelity 10 Tube Armstrong.

Designed for those who demand the highest possible fidelity in radio reception, the Collins FM-AM Tuner utilizes the most advanced engineering principles and finest in component parts. Two separate and distinct tuners are used having only the audio and power supply common to both. This 17-tube quality tuner features voltage stabilization; and a specially developed tuning eye in the F.M. circuit. A full line of accessories is available for the Collins Tuner.

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COLLINS Audio Products Co., Inc.

P. O. BOX 368 • WESTFIELD, N. J. • WE-2-4390

able to anyone interested, and the society's president anticipates formation of similar groups throughout the country.

New Microwave Chains

THE FCC HAS authorized the American Telephone and Telegraph Co. to construct two experimental microwave relay chains—one between Chicago and Milwaukee and the other linking Detroit and Toledo—to provide common carrier service including television transmission. Equipment and services proposed are similar to those now in effect in the New York-Boston microwave chain. Construction is to be completed by June 15, 1949 at an estimated cost of $1,400,000.

Name NEC Officers

THE NATIONAL ELECTRONICS CONFERENCE, INC., which will hold its annual technical forum Nov. 4, 5 and 6 at the Edgewater Beach Hotel, Chicago, Ill., has named W. C. White of General Electric Co., Schenectady, N. Y., as chairman of the board of directors for 1948.

Other officers elected are:

President—E. O. Neubauer of Illinois Bell Telephone Co.

Executive vice-president—G. H. Fett of the U. of Illinois.

Secretary—R. R. Buss of Northwestern Technological Institute.

Treasurer—O. D. Westerberg of Commonwealth Edison Co.

Vice-president in charge of arrangements—Karl Kramer of Jensen Mfg. Co.

Vice-president in charge of program—H. A. Leedy of Armour Research Foundation.

Vice-president in charge of publicity—L. G. Killian of Cook Research Laboratories.

Vice-president in charge of publication—A. H. Wing of Northwestern Technological Institute.

Chairman of exhibits committee—J. A. M. Lyon of Northwestern Technological Institute.

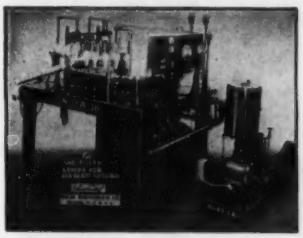
Chairman of hotels committee—R. K. Metcalf of Illinois Bell Telephone Co.

Oak Ridge to Have Graduate School

A GRADUATE engineering practice school for training in atomic energy plant work will be established in July at Oak Ridge, Tenn., by the Massachusetts Institute of Technology. The production plants of the Atomic Energy Commission at Oak Ridge will be utilized in the work. These include the gaseous diffusion and electromagnetic plants and the Oak Ridge National Laboratory.

Courses (five months each) will be open only to United States citi-

EISLER
ELECTRICAL & ELECTRONIC
EQUIPMENT
ELECTRONIC TUBE EQUIPMENT



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TRANSFORMERS OF ALL TYPES

For LIGHTING POWER FURNACES PHASE CHANGING DISTRIBUTION ETC.

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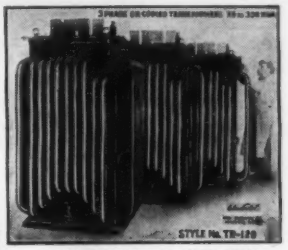
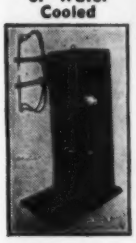
Air, Oil, or Water Cooled





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OF ALL TYPES
FOR ALL PURPOSES
SIZES ¼ to 250 KVA

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The "All-Weather" Resistors

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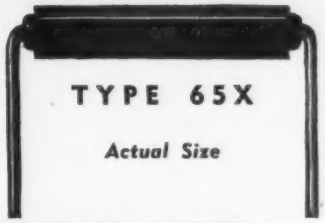

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1000 OHMS TO 10 MEGOHMS
Used extensively in commercial equipment including radio, telephone, telegraph, sound pictures, television, etc. Also in a variety of U. S. Navy equipment.

HIGH VALUE RANGE
15 to 1,000,000 MEGOHMS
This unusual range of high value resistors was developed to meet the needs of scientific and industrial control, measuring and laboratory equipment—and of high voltage applications.

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It gives details of both the Standard and High Value resistors including construction, characteristics dimensions, etc. Copy, with Price List mailed on request.

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Power Resistor DECADE BOX

★Here's a "must" for every well-equipped lab, plant, school, service shop, ship, etc. Solves resistance problems under actual working conditions. No calculations. No guesswork. No extensive experimentation. Instead, just insert in circuit, adjust decade knobs until best results are attained, then read correct resistance value right off dials!

Covers resistance range of 1 ohm to 999,999 ohms.

Each decade dissipates up to 225 watts. Greenohms (wire-wound cement-coated power resistors) used throughout. Glass-insulated wiring.

Six decade switches. Direct-reading in ohms. Maximum current per decade: 5, 1.5, .5, .15, .05 and .005 amp.

Frosted-gray metal case. Etched black-and-aluminum panel. Dual binding post terminals for left and right hand duty.

Grille at bottom and louvres at side and top for adequate ventilation.
13" long; 8½" deep; 5¾" high, 11 lbs.

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†Bulletin 114 sent on request. Let us quote on your resistance and control needs.

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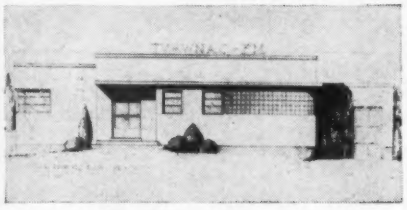
zens who are graduate students of the MIT engineering departments and who have been cleared by the Atomic Energy Commission. No compensation will be paid students, but academic credit will be given for work done. The major objective will be to help prepare graduate engineers for responsible posts in the atomic energy field.

BUSINESS NEWS

SUPREME, INC., Greenwood, Miss., a new corporation, has acquired the manufacturing rights, facilities and assets of the Supreme Instruments Corp., manufacturers of test equipment and meters, and will soon occupy its new air-conditioned plant.

YANKEE NETWORK'S new WNAC-TV-FM transmitter is under construction in Medford, Mass. Both the television and f-m antennas will



Architect's sketch of WNAC-TV-FM Transmitter building

be mounted on the same pole atop a 467-ft tower. Effective radiated power of the television antenna will be 32.7 kw.

LOCKE INCORPORATED is the new name for the Locke Insulator Corporation of Baltimore, Md. Having enlarged its design and development engineering staffs, the company will produce all types of ceramics and hardware for the electronic field.

PHILCO CORP. will design and produce fixed-station and mobile radiotelephone facilities for 21 cities throughout New England and New York, for rental by the U-Dryvit Auto Rental Co., Inc., Cambridge, Mass. along with its vehicles. At present, U-Dryvit operates a 100-

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Screws . . . nuts . . . washers . . . pins . . . Allmetal carries the largest stock in the country of stainless steel fasteners and screw machine parts. We also have facilities for heading, tapping, drilling, reaming, slotting, turning, stamping, broaching and centerless grinding . . . and we work not only with stainless and monel, but also with duralumin, aluminum, brass, bronze, or any other non-corrosive metal. All parts produced to close tolerances. Write for our catalog today. Allmetal Screw Products Co., 33 Greene St., New York.

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SPECIALISTS in STAINLESS FASTENERS

unit system in the Boston area under FCC limited common carrier radiotelephone authorization.

EMELOID CO., INC., makers of plastic products such as radio dials, electronic parts and name plates,

New Emeloid plant

recently moved to a new 40,000-sq ft plant in Hillside, N. J.

LINDBERG ENGINEERING CO. of Chicago, Ill., manufacturers of industrial heat treating and melting furnaces, has acquired the assets of the Electronics Division of Illinois Tool Works, and will continue to produce and sell h-f induction and dielectric heating equipment.

THE HAYS CORP., Michigan City, Ind., has added a new building to its manufacturing plant to provide for production of industrial electronic control instruments.

STANDARD ARCTURUS CORP. recently moved to a new plant in Newark, N. J., thus increasing plant capacity for tube development and

New Arcturus plant at 54 Clark St. in Newark

production and providing expansion space for its affiliates.

ROWE ENGINEERING CORP., Chicago, Ill., is the newly formed organization of the Rowe Radio Research Laboratory Co. Rowe Radio will continue to operate simultaneously until completion of several govern-

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Speer graphite anodes help Raytheon make better tubes

To radio enthusiasts, the name Raytheon on tubes means quality, service and performance. In making the 1006/ck1006 gas-filled rectifier, shown below, Raytheon specifies 2 Speer graphite anodes because of their unvarying high quality.

For all radio and electronic uses Speer Carbon Company produces graphite anodes of high thermal conductivity and emissivity. These characteristics enable them to radiate a maximum amount of heat from a given area and make it possible for tubes to handle up to three times as much input power as those with metal anodes. Cool operation of Speer graphite anodes assures longer tube life and efficiency of adjacent tube parts. Speer anodes perform excellently in stationary, mobile or portable equipment.

LOOK FOR GRAPHITE ANODES WHEN YOU'RE LOOKING FOR BETTER TUBES

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CARBON COMPANY
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brushes · contacts · rheostat discs · packing rings · carbon parts
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ALTEC LANSING News

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LEFT—Altec Lansing TI-401 Signal Generator contains 2 independent resistance-capacity sine wave oscillators. Weight: 34 lbs. Dimensions: 12¼H x 19W x 8½D.

RIGHT—Altec Lansing TI-402 Intermodulation Analyzer. Weight: 45 lbs. Dimensions: 12¼H x 19W x 9½D.

ALTEC LANSING INTERMODULATION ANALYZER A VALUABLE MULTI-PURPOSE INSTRUMENT

Letters received by Altec Lansing demonstrate impressively that the Altec Lansing TI 402 Intermodulation Analyzer, used with the Altec Lansing TI 401 Signal Generator, has become an indispensable tool to:

(1) broadcasting station engineers, for the measurement and correction of intermodulation distortion in radio transmitters; for analyzing distortion in speech input equipment; for routine checking of speech input equipment; for building special equipment for broadcast purposes, such as echo devices, filters, line equalizers, system equalizers, sound effects, etc.;

(2) recording studio engineers, for checking cutter head performance and playback heads, amplifiers, compression devices, equalizers, etc.;

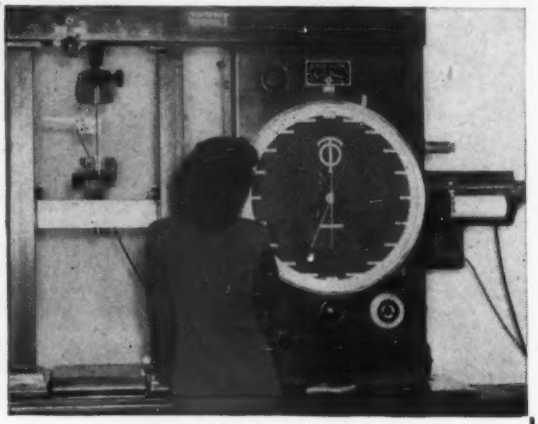
(3) film recording engineers, for optimum film recording, processing, and reproducing; and

(4) sound research laboratory engineers, for making progressive checks in the design and development of new electronic apparatus.

The many-sided usefulness of Altec Lansing Intermodulation test equipment is evidenced by the fact that over 200 firms, in all branches of the electronic industry, have purchased this equipment. Among users are: U. S. Department of State, International Broadcasting Division, and other government departments; WOR Recording Studios; and other major recording companies; Rudolph Wurlitzer Company; radio stations throughout the U. S.; motion picture producing companies; leading manufacturers of radios, radio-phonographs, electrical instruments, sound reproducing equipment and motion picture theatre sound systems; and many others.

Complete engineering data on Altec Lansing Intermodulation Test Equipment are available, and will be sent on request. Use address nearest you: 250 West 57th St., New York 19, or 1161 N. Vine St., Hollywood 38. Write to Dept. IT 3.

IF YOU WANT TO BE SURE... your plastic part is right for the job,



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Watertown service is a Complete Custom Service from formulating molding materials to the final buffing, polishing and assembly. In addition, Watertown's modern laboratory service keeps a careful check, step by step, on the progress of each job, thus insuring the customer an absolute minimum of costly rejects. Send us a drawing or a blueprint, or call in the Watertown representative in your vicinity. Sales offices are located in Cleveland, Chicago, Detroit, Milwaukee and New York.

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Periodic testing of all molded parts from basic material to finished product is routine in Watertown's completely equipped laboratory. Accurate readings in flexural, tensile and compressive strengths, as well as stress and strain curves are obtained from the machine illustrated specifically designed for the fatigue testing of plastics. Fissures, porosity and stray metal inclusions are detected by a new electronic X-ray unit.

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A NAME AS OLD AS THE PLASTICS INDUSTRY

ment contracts. The new organization specializes in consulting engineering and design and development projects covering electronics and nucleonics.

WESTERN ELECTRIC CO. will erect a new building covering an area equal to four entire city blocks in New York City to consolidate its headquarters organization.

ECKERT-MAUCHLY COMPUTER CORP. has moved to new and larger quarters in the Spring Garden Building, Broad and Spring Garden Sts., Philadelphia, Pa.

RADIO CORP. OF AMERICA recently began construction of a new building at its Lancaster plant as part

Artist's sketch of RCA's expanded tube plant at Lancaster, Pa.

of a million-dollar expansion program to increase c-r television picture tube production.

GRAY RESEARCH AND DEVELOPMENT CO. INC., makers of recording and transcription equipment, have moved to a larger factory in Hartford, Conn., to expand manufacturing facilities.

SPELLMAN TELEVISION INC., manufacturers of 30-kv h-v power supplies and other projection television components, have moved to larger quarters at 130 W. 24th St., New York City.

UNITED TELEVISION MFG. CORP., Boston, Mass., has been established to build home, restaurant and hotel television receivers.

ARNOLD B. BAILEY CORP., Scotch Plains, N. J., has announced the Bailey f-m transmitter which uses a highly stable f-m crystal operating at frequencies up to the limit

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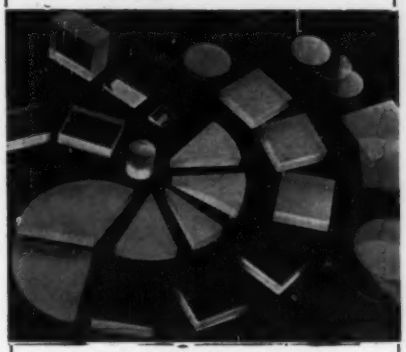
To Meet Your Needs in ALL

ULTRASONIC Applications



Special Cut Crystals from 50 KC. to 30 MC.

With or without silvered electrodes.
Dimensions to your specifications.

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Craftsmanship in Crystals Since 1931

For Visual Display of Reflected Energy

The
MEGA-MATCH

DISPLAYS MIS-MATCH
over wide frequency range

- 10 to 250 MC and up. Complete television and FM coverage.
- Completely electronic. No slotted lines, moving parts, bridges, or other frequency sensitive devices such as directional couplers.
- Precision frequency meter.
- Saves engineering time—Visual display presents instantly data which would take hours to tabulate.
- Can be adapted for balanced lines.

Completely Electronic

This unique instrument presents a visual display of REFLECTED energy over any band up to 30 MC. By the use of the MEGAMATCH it is possible to instantly observe and measure mismatches. Thus this instrument will check transmission lines, antennas, input and output impedance of amplifiers, converters, transforfers, etc.

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23 pgs. Radio & Television Sets • 62 pgs. Radio Parts
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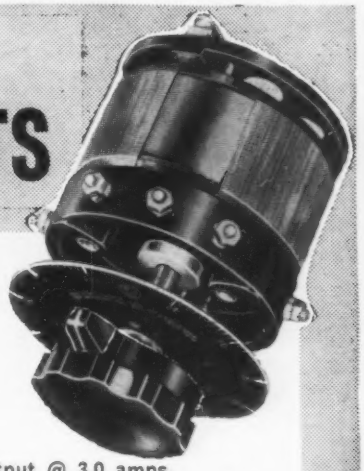
SUPERIOR POWERSTATS



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TYPE 20: 115V. input, 0-135 V. output @ 3.0 amps. 0.4 KVA	$12.50
TYPE 116: Mounted; 115V input, 0-135 V. output @ 7.5 amps. 1.0 KVA	23.00
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TYPE 1126: 115V. input, 0-135 V. output @ 15.0 amps. 2.0 KVA	46.00
TYPE 1226: 230V. input, tapped at 115 V., 0-270 V. output @ 9.0 amps. 2.4 KVA	46.00
TYPE 1156: 115V. input, 0-135 V. output @ 45.0 amps. 6.1 KVA	118.00

If not rated 25% with order, balance C.O.D. All prices F.O.B. our warehouse New York. We ship to any part of the globe. Write Dept. EL

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LENKURT KNOWS HOW

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WITH CUSTOM-BUILT FEATURES

Designers and Manufacturers of Broadcast Speech Equipment, School Sound Systems and Recording Equipment.

Designed and Fabricated by the Manufacturers of High Quality Sound and Recording Equipment for the Motion Picture Industry.

Bardwell & McAlister's new line of Commercial Amplifiers answers the great demand of sound engineers for commercial amplifiers embodying the principles used in "custom-built" units which have been successful in the sound equipment of the motion picture industry. These principles result in high fidelity reproduction at any setting of volume controls up to full rated output with less than 4% distortion, versatility of application, ease of operation and the longer life found only in Bardwell & McAlister Studio Quality Amplification Systems. Manufactured by Union Craftsmen and fully licensed.

Write for our sound equipment catalog and technical bulletins. Dealer inquiries invited.

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A BM INC PRODUCT

ELECTRONIC DIVISION
BARDWELL & McALISTER, INC.
BOX 1310, HOLLYWOOD 28, CALIFORNIA

of crystals now available. This newly formed concern will specialize in development of electronic communication equipment.

GARSTANG-MAY CO., Indianapolis, Ind., representatives of radio and electrical manufacturers, was recently formed by the former president and general manager and the vice-president in charge of manufacturing, respectively, of Electronic Laboratories.

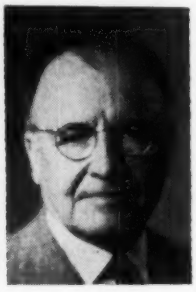
WESTINGHOUSE ELECTRIC CORP. has purchased additional manufacturing facilities at Hahntown, near Irwin, Pa. The new plant, with 125,000 sq ft of floor space, will be occupied by the mica-processing section of the transportation and generator division.

WESTERN SOCIETY OF ENGINEERS moved to new headquarters at 84 East Randolph St., Chicago, Ill.

PERSONNEL

MELVILLE EASTHAM, chief engineer of General Radio Co., Cambridge, Mass., recently received the New England Award for outstanding professional contributions to the industry, given annually by the Engineering Societies of New England, Inc. He founded General Radio in 1915, was its president until 1944, and was responsible for the development of Loran at MIT.

M. Eastham



J. H. Dellinger

J. HOWARD DELLINGER, chief of the Central Radio Propagation Laboratory of the National Bureau of Standards, recently retired after 40 years of government service. He initiated radio research at the

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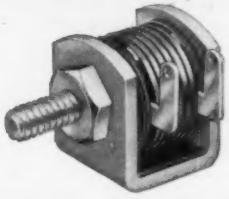

Really a miniature, this new Bradley Selenium Rectifier is ½" x ½" x 5/16". Low-priced but built for dependable operation over wide temperature variation. Completely sealed. Rated 110-125 Volts AC RMS, 20 ma DC continuous. Ideal for television pre-selectors, pre-amplifiers, relays and all other low current uses.

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Illustrated literature, available on request, shows Bradley's full line of photo cells and copper oxide and selenium rectifiers.

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Bureau in 1911 and discovered the simultaneous occurrence of solar eruptions and radio fadeouts, since called the Dellinger Effect. In the advisory field he organized the Interdepartmental Radio Advisory Committee which assigns all radio frequencies used by Federal agencies.

MARCUS A. ACHESON was appointed chief engineer for the radio tube division of Sylvania Electric Products Inc. He has been with the company since 1934 and during the war he directed the Sylvania development of proximity fuze tubes for the Navy Bureau of Ordnance.

M. A. Acheson

A. C. De Napoli

A. C. DE NAPOLI, previously with Western Electric Company and Films, Inc., has been named chief engineer of SoundScriber Corp., New Haven, Conn., manufacturers of electronic disc dictating equipment.

ANTHONY WRIGHT, recently appointed chief television engineer of The Magnavox Company, previously held the same position at RCA Victor.

NORMAN WUNDERLICH is now vice-president and divisional chief of Lear Radio, Inc., Chicago, Ill.

MAXWELL K. GOLDSTEIN, at one time head of NRL's radio direction finder activity, recently joined the staff of the research division of the Office of Naval Research as electronics consultant.

KENNETH V. CURTIS, application engineer in Raytheon's marine department since 1945, has been

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BULLETIN 270
"Potentiometers"

Concise, factual information on Rubicon Type B High Precision Potentiometer, Type C Microvolt Potentiometers (single and double), Type D Microvolt Potentiometers, Portable Precision Potentiometers, Type S Students' Potentiometer, Temperature-Calibrated Potentiometers, Brooks Model 7 Deflection Potentiometer, and accessories including volt boxes, standard cells, keys and batteries.

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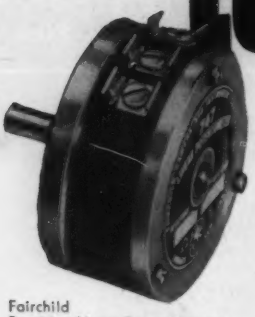

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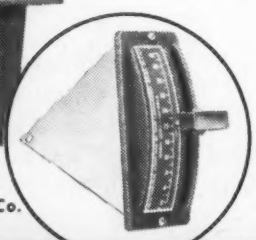

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Write for Descriptive Bulletin

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named product manager of the commercial products division at Raytheon Mfg. Co., Waltham, Mass. From 1943 to 1945 he was in the radar design section of the Bureau of Ships, USN.

FRANK G. MARBLE has been appointed sales manager of the Kay Electric Co., of Pine Brook, N. J. He was recently in charge of instrumentation activities at Pratt and Whitney Aircraft. During the war he was associated with the Bell Telephone Laboratories in connection with radar activities.

F. G. Marble

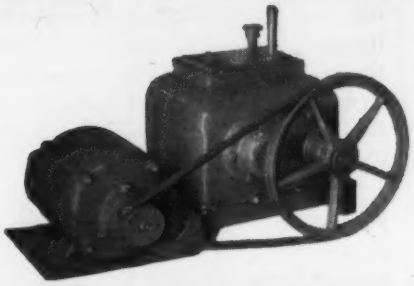
R. K. McClintock

R. K. MCCLINTOCK was named assistant to the chief engineer at Sylvania Electric's radio tube division. He has been with the company since 1936 and was instrumental in the development of the proximity fuze.

R. E. MATHES, previously associated with RCA Laboratories, with radar countermeasures in the Bureau of Ships, and until recently chief engineer of Finch Telecommunications, is now chief engineer at Gray Research and Development Co., Inc., Elmsford, New York.

NOEL L. KEEFER, for the last 12 years chief installation and service engineer on the Pacific Coast for General Electric Co., has been appointed chief engineer of KMGM, Metro-Goldwyn-Mayer's f-m station in Los Angeles.

WILLIAM H. LYON, former service engineer, has been appointed service manager at SoundScriber Corp. During the war he was an associate engineer in the Interior Communications Section of the Bureau of Ships.



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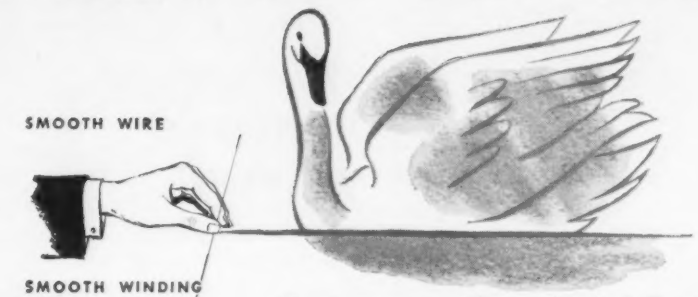

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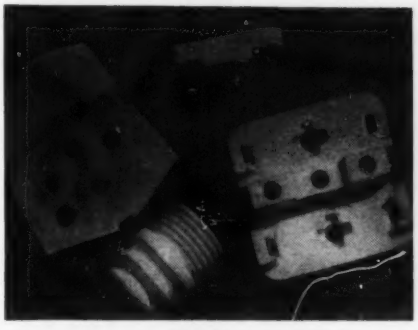

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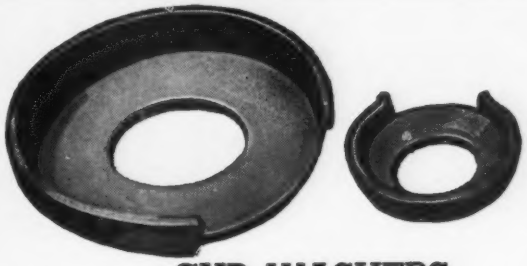

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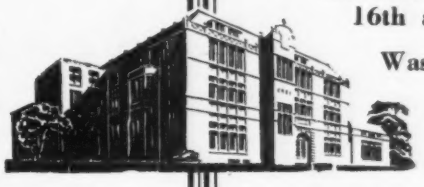

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NEW BOOKS

Hearing Aids

By H. DAVIS, S. S. STEVENS, R. H. NICHOLS, JR., C. V. HUDGINS, R. J. MARQUIS, G. E. PETERSON AND D. A. ROSS. *Harvard University Press, Cambridge, Mass.*, 1947, 197 *pages*, $2.00.

THIS book describes work done at Harvard University during the war on the adaptation of hearing aids to individual users. The work had two original objectives: (1) the determination of frequency-response patterns in a hearing aid which would give best performance for people with various types of hearing loss and (2) the development of rapid and reliable methods for testing hard-of-hearing people.

The principal item of physical equipment used in the research was a "master hearing aid", which consisted of a laboratory-type microphone, amplifier, receiver, and controls.

The method of testing was concerned primarily with the intelligibility of speech as determined by the use of word lists. Tone quality and ease of listening were not considered in the merit rating.

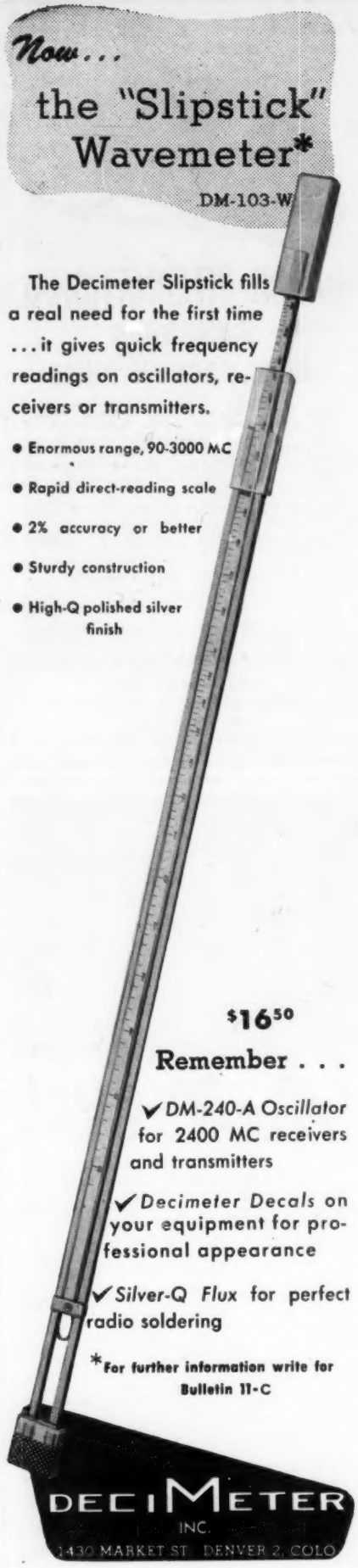
The tests were conducted on a group of eighteen hard-of-hearing men and women with hearing losses ranging from moderate to severe.

The articulation tests on the word lists were conducted both to determine types of frequency patterns as related to hearing losses shown in audiograms for different individuals and also to determine desirable loudness and methods for limiting loudness.

The principal conclusion drawn on the first of these items is that practically all hard-of-hearing persons can be properly fitted with either a flat frequency response or with a response which has a simple and uniform rise with increasing frequency.

With regard to the second item it was concluded that it is desirable to limit maximum loudness for any individual and that this limiting may best be done by compression amplification, although peak clipping is also acceptable.

This report is a valuable summary of specific work done in the hearing aid field by a group of scientists. The validity of its general conclusions is impaired by the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small number of different persons tested and the fact that the criteria is based solely on articulation without regard to satisfactorily pleasing tone quality. The latter item is of great importance since experience shows that hard-of-hearing people will not wear a hearing aid continuously if the tone quality is annoying, no matter how good the articulation may be.

The danger of generalization on the basis of only eighteen users as well as on the somewhat questionable standard of articulation only is illustrated by data taken from the files of the Sonotone Corporation. From these records we have examined one thousand successive audiograms without selection and have compared them with the fittings on instruments which were found to give best longtime results. These data show that 48 percent of the one thousand individuals were fitted with frequency characteristics lying within the range of the Harvard recommendations; 52 percent were better fitted by frequency patterns lying outside the recommendations of the Harvard report.

The excessive emphasis given to this one generalization with regard to frequency fitting and the undue publicity given to this statement tend to discredit an otherwise worthwhile report on a valuable study of hearing aid problems.—L. GRANT HECTOR AND FRED W. KRANZ, *Sonotone Corp., Elmsford, N. Y.*

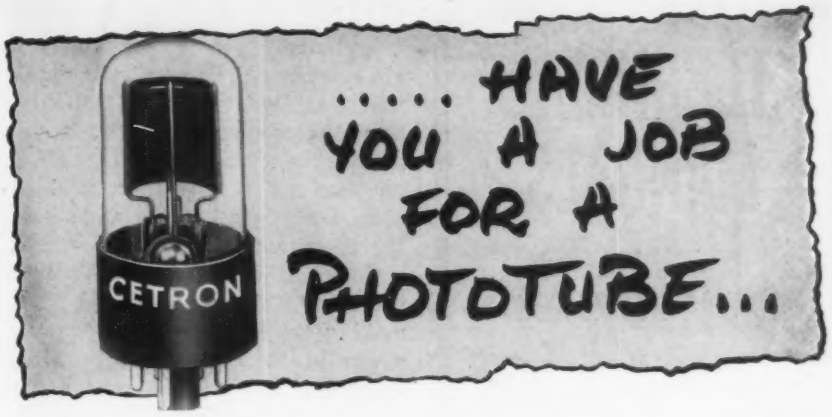
Patent Notes for Engineers

PUBLISHED BY RCA REVIEW, *RCA Laboratories Division, Radio Corporation of America, Princeton, N. J.*, 1947, 151 *pages*, $2.50.

WHILE published primarily for use within the RCA organization, the contents of this book will appeal to all engineers, scientists, and attorneys who have to deal with patent matters. Many of the questions which naturally arise in the minds of technical people will be found answered within its pages.

The original manuscript was prepared by C. D. Tusks, director of RCA's patent department, but the book also draws upon other members of the patent group.

Within the eight major chapters will be found explanations of what constitutes an invention, what can



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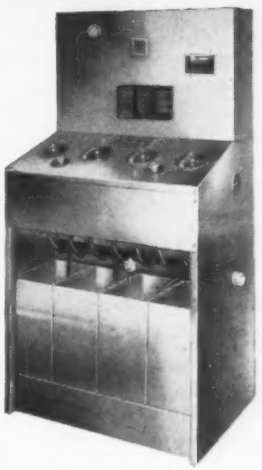

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NEW BOOKS (continued)

be patented, how to keep appropriate records of one's technical work that may lead to a patent application, the preparation of the application, its amendments, the whole question of interference, and finally, the ownership, use, and licensing of patents.

Copious examples from the patent literature point up the discussion, making the book more effective as a working tool and more interesting, even to one who may never make an invention. The entire technique of carrying matters through from the original concept to the use of an issued patent is covered.—K.H.

Radio Engineering

By Frederick Emmons Terman. *McGraw-Hill Book Co., New York*, 1947, *Third Edition*, 969 *pages*, $7.00. "Electrical circuits and vacuum tubes behave according to exact laws, which in the main are simple and easily understood, and which can be used to predict the performance of radio circuits and radio apparatus with the same certainty and accuracy that the performance of other types of electrical equipment, such as transformers, motors, and transmission lines, is analyzed. It is this ability to reduce a problem to quantitative relations that predict with accuracy the performance to be expected or explain the results already obtained that represents a real mastery of the subject such as the radio engineer is expected to possess." So reads a portion of the Preface to the First Edition. That it appears some fifteen years later in a much expanded Third Edition may be a hoary tradition of the publisher's routine, but it is none the less alive and, one suspects, a reaffirmation of the author's creed.

For all his uncompromising approach to the fact that there can be no royal road, nor primrose path either, to engineering, Professor Terman has managed to keep the presentation of information in his books clear and simple, so that "Terman says . . ." has become a natural preamble in classroom or laboratory. Although his scholastic attainments have brought him the title of Dean of the School of Engineering at Stanford University, he is probably better known as past

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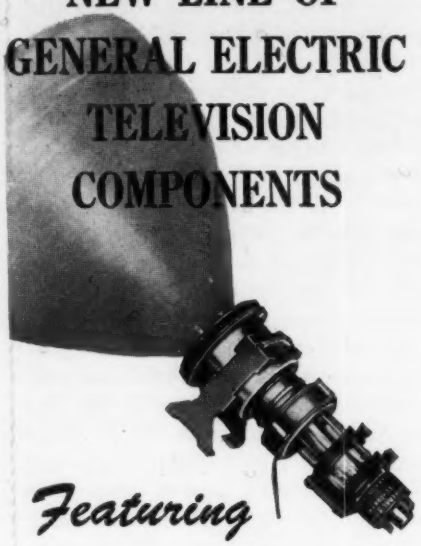

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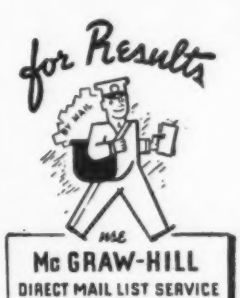

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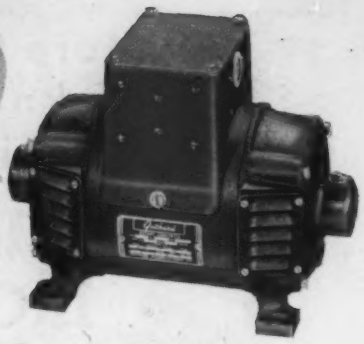

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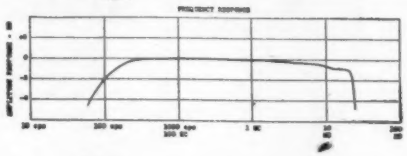

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president of the Institute of Radio Engineers. No mere pedant, he served his country with distinction at the MIT Radiation Laboratory, from whence he moved his group to found the Radio Research Laboratory at Harvard.

We are dealing here with a college text that will not necessarily please everyone. It is not a handbook with a quick answer for the man who suddenly wishes to know all about a new electronic aid to navigation, nor is it a loose-leaf booklet into which one slips dope sheets on the latest equipment for the production of frequency modulation.

The text as a whole has been brought up-to-date by the inclusion at appropriate points of such information as that on klystrons, magnetrons, lighthouse and traveling wave tubes. In addition, a completely new chapter has been added that describes circuits with distributed constants and serves to orient the reader on microwave phenomena. It would be hopeless to attempt a complete catalog of contents and additions, particularly since there are already at least 105,000 readers who are familiar with the general philosophy and presentation of the original work.

Fifty-odd pages of questions from the separate chapters have been collected at the back of the volume where they are more conveniently found than in earlier editions.—A.A.McK.

Microwave Mixers

Volume 16 of the MIT Radiation Laboratory Series, By Robert V. Pound. *McGraw-Hill Book Co., New York*, 1948, 381 *pages*, $5.50.

THE present state of the art in microwave mixer circuits and components is well covered in this volume. Although the microwave superheterodyne receiver and crystal rectifiers are themselves subjects of other volumes in the series, sufficient introductory material is presented here to permit the reader to study microwave mixers and their use without recourse to the other volumes.

Because of their wide usage, crystal mixers are the major topic of this text. Simple, multiple-function and balanced mixers are considered. The local oscillator is con-

sidered not only with regard to noise generation but to frequency control as well. A chapter by Eric Durand discusses various local oscillator frequency stabilization methods, including constant frequency difference and constant absolute frequency schemes.

The completeness of the text, its use of but lack of dependence on mathematics, the large number of practical design problems considered and the detailed drawings and data presented make this text very useful. Anyone desiring to know more about this field of microwave techniques would do well to read this book.—JOSEPH KAUFMAN, *National Radio Institute, Washington, D. C.*

Techniques in Experimental Electronics

BY C. H. BACHMAN, *Associate Professor of Physics, Syracuse University. John Wiley & Sons, New York,* 1948, 252 *pages,* $3.50.

IN this short book the author, formerly with G-E, describes the equipment and methods used in laboratory vacuum systems, especially with electronic discharge devices. Liberal comparisons and evaluations of the methods discussed make the book a useful guide; practice is stressed rather than theory.

About the first two-thirds of the book is devoted to vacuum systems: pumps, traps, baffles, gages, valves and controlled leaks, demountable joints, glass blowing, leak detection, glass systems, and metal systems. The last third of the book discusses electronics: cathodes and sources of charged particles, control, and assembly and processing in the laboratory. Two chapters, one on controls and gadgets and one on hints and techniques, contain many suggestions based on experience that can save others the need for learning the hard way.

As a comprehensive discussion of the subject, the book is especially valuable for the specific mentions of materials and equipment that have proved suitable under various conditions. The treatment is well adapted to the needs of the beginning experimenter concerned with simple vacuum and electronic problems, such as the graduate student. It should be supplemented with

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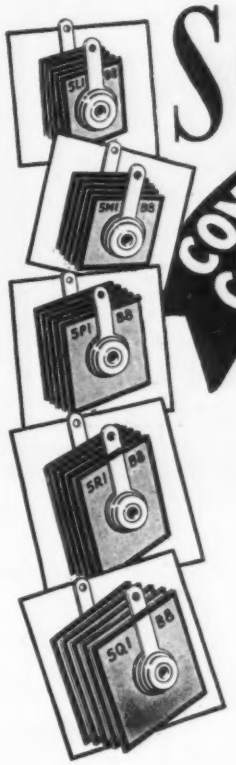

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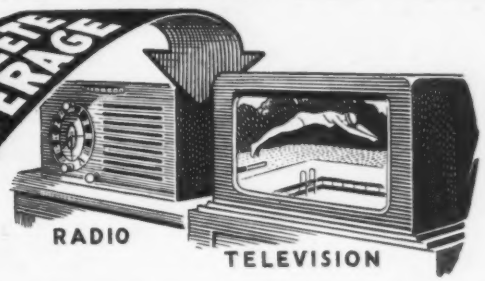

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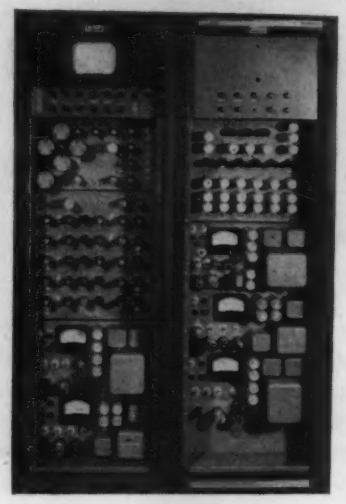

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Crystal Rectifiers

Vol. 15 of the MIT Radiation Laboratory Series, EDITED BY HENRY C. TORREY AND CHARLES A. WHITMER. *McGraw-Hill Book Company, New York*, 1948, 443 *pages*, $7.50.

EARLY in the development of microwave radar it was found that the old familiar crystal rectifier, in suitably modernized form, offered considerable promise as a high-sensitivity mixer crystal. With further development, improvement in sensitivity, stability and ruggedness resulted in a reliable component, superior in performance to any vacuum tube, which was universally used in microwave radar mixers. It is not surprising, therefore, that an appreciable percentage of the total research and development effort of the microwave radar program was devoted to crystal rectifiers.

The MIT Radiation Laboratory not only carried out a broad research program in all aspects of the crystal rectifier but also coordinated the simultaneous research programs of many university and industrial laboratories. The purpose of the book is "to present the fund of knowledge on crystal rectifiers that accumulated during the course of World War II".

Although the main application was that of mixer crystals, the low-level video rectifier for microwave beacon systems was of considerable importance. Crystals were also widely used in laboratory measurements, particularly for wavemeter resonance indication and relative power measurements.

After a discussion of the properties of semi-conductors from the present theories of the solid state, a summary is given of the most recent theories applicable to the semi-conductor point-contact rectifier. A major portion of the book is devoted to the crystal converter and includes thorough treatment of the crystal characteristics of conversion loss, noise, r-f and i-f, impedances and burnout properties. The remainder of the book is devoted to special types including the video detector crystals. Representative manufacturing techniques are given for the various

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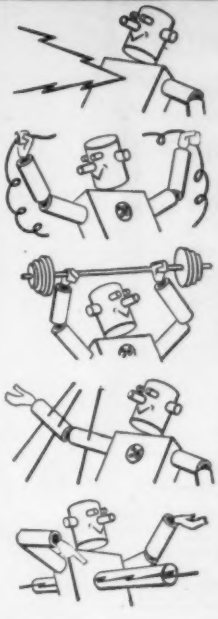

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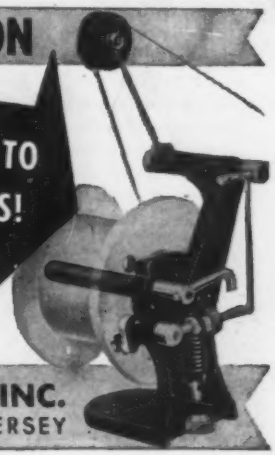

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crystal types as well as a discussion of the various measurement techniques. This includes both laboratory methods for comprehensive measurements and detailed descriptions of standardized test equipment for production testing of crystals for the most important frequency bands.

Probably the most outstanding development in this field was the discovery during the war by Benzer, of Purdue University, of the high-inverse-voltage germanium rectifier. Although developed too late for application during the war, this rectifier has already attained considerable commercial importance in communication and electronic equipment.

Summarizing as it does the entire field of crystal rectifier development during the war, this authoritative book may be highly recommended to physicists interested in the theory of semi-conductors and point-contact rectifiers and to microwave and communication engineers interested in the properties and applications of crystal rectifiers.—H. HEINS, *Sylvania Electric Products Inc.*

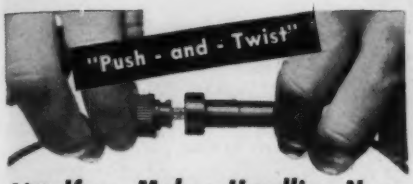
Books Received for Review

DICTIONARY OF GERMAN ELECTRICAL SYMBOLS. Office of Technical Services, Department of Commerce, Washington 25, D. C., 120 pages (printed), $3.00. Approximately 1,200 symbols used to designate components of German communication systems, each identified according to conventional American designation. Includes symbols for switches, relays, tubes, radar components, etc.

MODERN COLLEGE PHYSICS. By Harvey E. White. D. Van Nostrand Co., Inc., New York, N. Y., 1948, 802 pages, $5.00. Designed for use as standard required one-year college physics course. The entire last quarter of the book is devoted to electronics as well as atomic and nuclear physics. The book is intentionally too big for a one-year course, and is divided into many chapters so instructors can pick and choose.

MODERN PHYSICS. By G. E. M. Jauncey. D. Van Nostrand Co., Inc., New York, N. Y., 1948, third edition, 561 pages, $6.00. Intermediate between first-year course in college physics and advanced undergraduate physics courses. Revisions serve chiefly to cover advances made in physics since publication of the second edition in 1937.

UNITED STATES NAVY SYNCHROS—Description and Operation. Ordnance Pamphlet No. 1303, 15 Dec. 1944, available from Superintendent of Documents, Government Printing Office, Washington 25, D. C. as catalog No. N 18.7:1303, price 50 cents, 166 pages. Paper-covered manual intended for technicians who maintain and repair Synchro systems, called Selsyns by G-E, Teletorque by Kollsman and Autosyn by Bendix. Covers fundamentals, motors and generators, a



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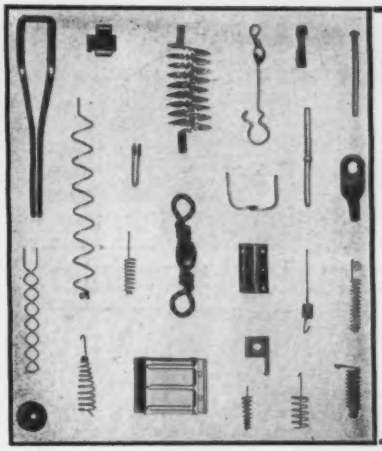

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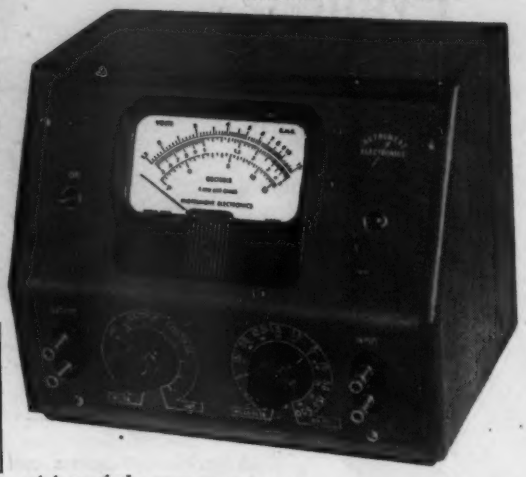

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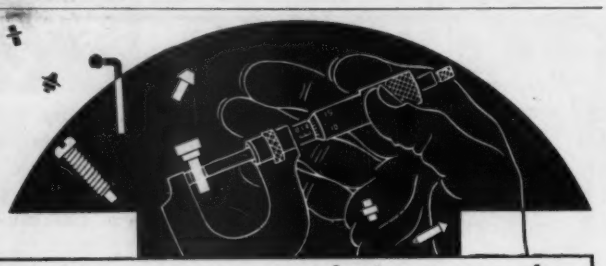

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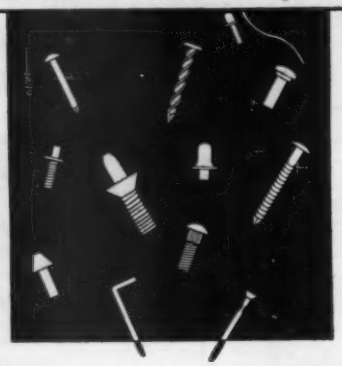

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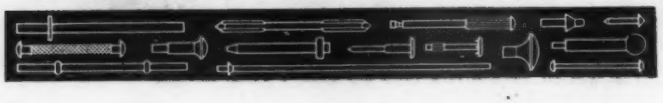

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FREQUENCY MODULATION, Volume I. Published by RCA Review, Princeton, N. J., 1948, 515 pages, $2.50. Reprints of papers by RCA authors covering the period 1936-1947, in four sections: General; Transmission; Reception; Miscellaneous. Additional papers are included in summary form or are listed in the bibliography at the end of the book. Cloth-bound.

ELEMENTARY RADIO SERVICING. By William R. Wellman. D. Van Nostrand Co., Inc., New York, N. Y., 1947, 260 pages, $3.00. Troubleshooting and repair, for vocational school students and others who have already studied radio and mastered some of the principles of receiver construction. Forty job sheets at ends of chapters give step-by-step instructions for carrying out laboratory experiments. No mathematics, and minimum theory.

THE LOG LOG SLIDE RULE. Written and published by Edward C. Taylor, Woodstock, Vermont, 24-page booklet, $1.00. Advanced instruction pamphlet telling how to use the log log rule for solving practical problems in which exponentials, natural logarithms, decimal powers and hyperbolic functions have to be evaluated numerically.

ELECTRIC RESISTANCE WELDING. Published by Harold S. Card, 850 Euclid Ave., Cleveland 14, Ohio, 22 pages, $1.00. Nearly 650 articles published in 49 magazines from 1936 to June 1947 are listed chronologically by publication. An index provides a subject key to the bibliography.

TABLES OF SPHERICAL BESSEL FUNCTIONS, VOL. 11. Mathematical Tables Project, National Bureau of Standards, Columbia University Press, New York, 1947, 328 pages, $7.50. This volume extends the range for $\pm\nu$ from 29/2 to 61/2, Vol. I having covered the range from 1/2 to 27/2, for the Spherical Bessel Function $(\pi/2x)^{1/2}J_\nu(x)$.

DISSOCIATION ENERGIES AND SPECTRA OF DIATOMIC MOLECULES. By A. G. Gaydon. John Wiley & Sons, Inc., New York, 1947, 239 pages, $5.00. American edition of a British book covering this aspect of molecular spectroscopy. Final chapter gives numerical data for about 250 diatomic molecules. Electron impact methods are covered in chapter VII.

BRITISH RADIO COMPONENTS. Radio Component Manufacturers' Federation, 22 Surrey St., Strand, London WC2, England, 1947, 184 pages, 21 shillings. Addresses of members, achievements of British radio industry, classified index of British-made radio components, advertisements of manufacturers and list of trade names.

STANDARDS ON RADIO RECEIVERS—Methods of Testing Frequency-Modulation Broadcast Receivers. The Institute of Radio Engineers, New York 21, N. Y., 1947, 15 pages, 50 cents. Sequel to 1938 report dealing with a-m receivers, limited to broadcast f-m receivers designed to operate at carrier frequencies between 88 and 108 mc.

RADIO DATA BOOK. By W. F. Boyce and J. J. Roche. Boland and Boyce, Inc., Publishers, Montclair, N. J., 1,148 pages, $5.00. Handbook format, presenting 200 pages of basic circuits without values of components, a hundred pages on test equipment, and sections on measurements, antennas, sound systems and sound recording. Tube data fills 325 pages; the remaining 263 pages cover formulas, graphs, tables, symbols, codes, 64 pages of complete circuit diagrams of radio equipment with values, an abridged dictionary of terms, and a glossary of radio books.

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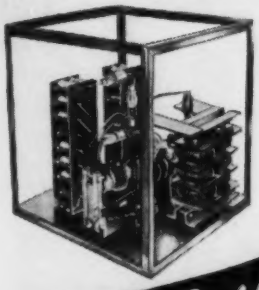

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Backtalk

This department is operated as an open forum where our readers may discuss problems of the electronics industry or comment upon articles which ELECTRONICS has published.

Phantastron Decimal

DEAR SIRS:

IN Table 2 of the article in the April issue of ELECTRONICS on phantastrons, all the values of delay in microseconds should be divided by ten; that is, 50 instead of 500, 250 instead of 2500, etc. This inadvertent misplacement of a decimal point would be somewhat embarrassing if a person built a phantastron using the values of the table and expected a delay ten times longer than they would get.

The values in the first column are for a circuit which worked. However, for circuits which have a small value of maximum delay time, the circuit is somewhat critical since the value of the grid condenser C_g, is beginning to approach the value which one might expect for stray capacitance in a badly laid-out circuit.

MATTHEW T. LEBENBAUM
Engineer
Airborne Instrument Laboratory
Mineola, New York

Audio Noise Reduction

DEAR SIRS:

HARRY F. Olson's statement (ELECTRONICS, Dec. 1947, p 120) that he separates signal and noise on the basis of amplitude is misleading.

It is true that the system he describes will discriminate against any amplitude below a certain threshhold level—*but only when said amplitude is present alone* (or with other sufficiently small amplitudes).

If a small noise voltage below the threshhold level and a signal voltage of such a magnitude as to make the sum of the signal voltage plus the noise voltage greater than the

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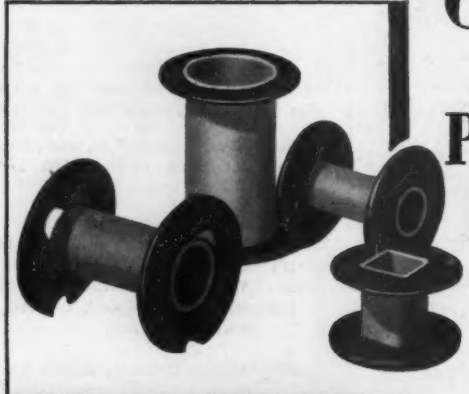

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threshhold level are simultaneously present, no separation of signal and noise will occur.

The statement that if the threshhold level "corresponds to the maximum amplitude of the noise, the noise will not be reproduced" is accordingly incorrect, except under special conditions not usually attained.

There can be no improvement in signal to noise ratio by use of the system he describes except during intervals when the sum of the signal plus the noise is less than the threshhold level—which is of course a trivial consideration.

HENRY E. SINGLETON
New York, N. Y.

Rebuttal

DEAR SIRS:

I am glad that Henry E. Singleton has called attention to some parts of my paper that were not clear because it provides me with an opportunity for additional explanation and clarification.

It is impossible in a discussion or in an article describing the system to present the complete theory of electronics involved and all the characteristics of speech and music which conspire to make the system effective in reducing noise. Since the elements of sound reproduction, such as, for example, time-frequency distribution of the components in speech and music, masking of noise by tones, threshold and ambient noise, integrating characteristics of the ear, are known to those interested in sound reproduction, it appeared superfluous to present these in the article. Rather I tried to present the physical action of the system.

Of the above characteristics, there is one outstanding one, namely, the transient nature of speech and music that makes it possible to reduce noise by threshold system. If the frequency range is divided into octave frequency bands, it will be found that, in general, there are relatively long intervals in which there is no signal amplitude. However, the noise is always present.

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THIS CONTACTS SECTION supplements other advertising in this issue with these additional announcements of products and services essential to efficient and economical operation in the field of ELECTRONICS

when there is no signal, the noise will not be reproduced. Furthermore, when the noise and signal are of small amplitude there will be a reduction in noise. This is certainly separation of noise and signal on the basis of amplitude. Obviously, when the amplitude is several times the noise level the reduction is small. However, under the latter conditions, the signal masks the noise and noise reduction is not necessary. It may be mentioned in passing, that none of the existing noise-reducing systems are capable of reducing noise under full signal operation.

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HARRY F. OLSON
Radio Corporation of America
RCA Laboratories Division
Princeton, N. J.

Stagger Tuning

DEAR SIR:

I wish to disclaim responsibility for the captions accompanying the diagrams in my article "Stagger-Tuned Amplifier Design" in the May 1948 ELECTRONICS. In particular, Fig. 4 and 6 are interchanged, the numerical values in the caption of Fig. 2 are erroneous, and the word "flat" must be omitted in the phrase "flat staggered-pair" of the caption to Fig. 5.

HENRY WALLMAN
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

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(Continued from page 257)

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515 Madison Ave., New York 22, N. Y.

OSCILLOSCOPES SYNCROSCOPES
Complete repair service for all types of scopes
LERU LABORATORIES, INC.
360 Bleecker St., N. Y. 14. WA-9-4194

FOR SALE
Broadcast Transmitter
Western Electric Type D-87737 1000-watt broadcast transmitter modified for high fidelity. Being used daily on 1330 kc. Available about June first.
WBBR, Staten Island 2, N. Y.

COMMUNICATIONS RECEIVERS
All types expertly repaired and rebuilt to rigid factory specifications or better. Calibration, alignment, image rejection measurements etc., to highest standards. All service work guaranteed. Workmanship you can measure.
Authorized Hallicrafters and National Service Center
WINTERS RADIO LABORATORY
11 Warren Street New York 7, N Y. Cortlandt 7-1361

WANTED

WANTED
WESTERN ELECTRIC VACUUM TUBES
Types 101F, 102F, 272A, 274A or B, 310A or B, 311A, 313C, 323A, 328A, 329A, 348A, 349A, 352A, 373A, 374A, 393A, 394A, 121A Ballast Lamps.
W-4493, Electronics,
330 West 42nd Street, New York 18, N. Y.

WANTED
Type 101B 1000/20 cycle ringers manufactured by Federal. Type J68602 Ringer-oscillators manufactured by Western Electric.
W-4471, Electronics,
330 West 42nd Street, New York 18, N. Y.

WANTED
TEST EQUIPMENT
Here is an opportunity to convert your idle Laboratory Equipment into cash. Send description to
W-4861, Electronics
330 West 42nd Street, New York 18, N. Y.

WANTED
All type of surplus oil filter and bathtub condensers of G. E., Aerovox, C-D and Solar manufacture. Give detailed specifications, condition and quantities available. Will buy complete lots if price is right.
W-4009, Electronics
330 West 42nd Street, New York 18, N. Y.

WANTED
Western Electric Carrier Telephone, Carrier Telegraph Equipment and Components. Filters, repeating coils, transformers, equalizers. Types CF1, CF2, H, C, and other carrier equipment. Telephone and telegraph repeaters.
W-4435, Electronics
330 West 42nd Street, New York 18, N. Y.

WANTED
APR 4 Coils and Receivers
TN 16, TN 17, TN 18, TN 19 and TN 54.
Microwave equipment and all electronic parts in any quantity
W-4821, Electronics
330 West 42nd Street, New York 18, N. Y.

Wanted

★ PHYSICISTS
★ RADAR ENGINEERS
★ SYSTEMS ENGINEERS
★ ELECTRONIC ENGINEERS

To enable us to carry out our long-term engineering program on missiles, radar, communications, etc., we must add a considerable number of qualified graduate engineers with electronic, research design and/or development experience to our staff. Please furnish complete resume of education, experience and salary expected to: Personnel Manager

BENDIX RADIO DIVISION
Bendix Aviation Corporation
Baltimore 4, Maryland

RADAR ENGINEERS

Exceptional opportunity in
SOUTHERN CALIFORNIA

for engineers with creative design experience in RADAR and associated electronic and mechanical equipment. Attractive working conditions, first-rate plant facilities, salary commensurate with ability. State availability, salary expected, and complete details of experience.

Reply to
Personnel Manager
GILFILLAN BROS., INC.
1815 Venice Blvd.,
Los Angeles 6, Calif.

WANTED

AUDIO ENGINEER

Experienced in manufacture and test of radio loudspeakers, audio transformers and coils. Write details of education experience and personal history. State salary requirements.

BEST MANUFACTURING CO., INC.
1200 GROVE STREET, IRVINGTON, N. J.

ENGINEERS

PROGRESSIVE ELECTRONIC RESEARCH AND DEVELOPMENT COMPANY

has several openings for Senior Electronic Engineers of superior ability, with experience in design and development. Excellent opportunities for top flight men. Send complete resumes and salary requirements to:

Personnel Department

MELPAR, INC.

452 SWANN AVENUE, ALEXANDRIA, VIRGINIA

ELECTRONIC MAJOR

Offering recent graduate interested in electronic digital computers, permanent well-paying position. Submit letter detailing experience, personal data, education and salary.

P-4785, Electronics
520 North Michigan Ave., Chicago 11, Ill.

WANTED

MATHEMATICIANS, ENGINEERS, PHYSICISTS

Men to train in oil exploration for operation of seismograph instruments, computing seismic data, and seismic surveying. Beginning salary—open, depending upon background; excellent opportunity for advancement determined on ingenuity and ability. Nature of work requires several changes of address each year; work indoors and out; general locations in oil producing states. To apply, write, giving scholastic and employment background; age, nationality, marital status; and include recent snapshot to:

NATIONAL GEOPHYSICAL CO., Inc.
8800 Lemmon Ave. Dallas 9, Texas

"VIBROTEST" RESISTANCE AND VOLTAGE TESTER

Resistance Range 0-200 Megohms (at 1,000 volts test potential) 0-2000 Ohms

Voltage Range 150-300-600 Volts D.C. 150-300-600 Volts A.C.

Push button action for resistance readings. Operates from internal power supply off two #6 dry cells. Large 4" meter and knife edge pointer insure accurate readings. Complete with batteries, test leads & instructions in metal carrying case. Associated Research Inc. Model # 204.

Net Price $60.00 f.o.b. N. Y.

WESTON MODEL 311 PORTABLE POTENTIAL TRANSFORMER

To be used to extend the range of any precision laboratory standard 150 Volt A.C. meter.

Maximum potential ratio of 1500 and 750 volts to 150 Volts.

Normal potential ratio of 1150 and 575 volts to 115 Volts.

Frequency rating from 25-125 cycles. Maximum secondary burden of 15 volt-ampere. Ratio accuracy is within 1/5 of 1% when used with model 310 or 326 meters. Complete in polished oak case with removable cover, lock and carrying strap.

List Price $247.50

Net Price $90.00 F.O.B. N. Y.

WESTON MODEL 461-4 PORTABLE CURRENT TRANSFORMER

This unit can be used with any precision 5 Amperes A.C. Meter to extend the ranges of the meter to 50, 100, 200, 250, 500 or 1000 Amperes A.C. Accuracy within ¼ of 1%; Normal Secondary Capacity = 15 Va; Binding Posts for 50 Ampere tap: Inserted primary for 100, 200, 250, 500 and 1000 Amperes; Insulated for use up to 2500 volts.

List Price $98.00

Net Price $35.00 f.o.b. N. Y.

PANEL METER COMBINATION OFFER

150 Volts A.C. Meter, Triplett 331-JP 3½" Rd fl. bakelite case.

30 Ampere A.C. Meter, Triplett 331-JP 3½" Rd. fl. bakelite case.

Both Meters for $7.95

MULTI-RANGE PORTABLE A.C. VOLTMETER

Weston Model 433, 150/300/600 volts AC. Accuracy within ¾ of 1% from 25 to 125 cycles. Hand calibrated Mirror scale 4.04" long with 150 scale divisions; Knife edge pointer. Moving iron Band type. Magnetically shielded. Dimensions 6"x6"x3⅛" ..... **Net $47.50**

Voltage Polarity Phase Rotation Tester, Triplett 337 AVP. Checks 115, 220 and 440 line voltage; locates open circuits, blown fuses, damaged wiring, etc., Indicates whether A.C. or D.C. and polarity of D.C.; Checks phase rotation to determine direction of rotation of motors, operation of controls, etc.; Consists of a 3" square meter and a small polarized vane movement in a small handy sized case. Complete with 36" leads with test prods. @ **$8.50**

Portable (Chronometric) TACHOMETER

Jaeger Watch Co. Model #43A-6

- Can be used for speeds up to 20,000 R.P.M.
- Can be used for lineal speed measurements to 10,000 F.P.M.
- Ideally suited for testing the speeds of motors, particularly of fractional horse power, generators, turbines, centrifugals, fans, etc.
- Very small Torque—requires practically no power to drive.
- Unequalled Readability 2" Open face dial—each division on large dial equals 10 R.P.M.; each division on small dial equals 1,000 R.P.M.
- Greatest Accuracy—meets Navy specifications —guaranteed to be within ½ of 1%.
- Results of test reading remain on dial until next test taken.
- Push button for automatic resetting.
- Complete with the following accessories:

1—Large pointed rubber tip
1—Large hollow rubber tip
1—6" circumference wheel tip
1—Operating Instructions
1—Temperature Correction chart

The combination of the above features will give accurately, within a few seconds, by direct reading, the R.P.M. of shafts or the lineal speeds of surfaces without any accessories or timing of any kind. Each unit comes complete in a red velvet lined carrying case 5" x 3⅛" x 1½" (case and accessories not illustrated). **Net List Price, $75.00**—Surplus—New—Guaranteed.

Your Cost $24.50 fob, N. Y.

CODE TRAINING SET AN/GSC-T1

Made by T. R. McElroy, Boston

Operates off 6, 12, 24 or 110 V D.C. or 110 V or 230 Volt, 60 cycle.

An excellent unit for schools or clubs for code training. This unit is designed for group training of telegraph code to students whereby each student sends a message from any prepared text to the instructor. It provides a visual signal through a blinker or an audible signal through a monitoring speaker. Has volume control, variable frequency oscillator, a phone jack for a monitoring headset, pitch and tone control, rotary switch for selecting the operating voltage and power supply.

Complete with spare fuses, power cord and battery adapter; 10 Telegraph Keys with 10' line each, 1 #6x5 tube and 2 #6AG6 tubes.

Complete in chest 10½" x 17" L x 13½" H—Net wt. 49 lbs.

Can be used anywhere—batteries A.C. or D.C. Durable—Good for a lifetime of Service! NET fob, NY **$24.50**

PORTABLE A. C. AMMETER WESTON MODEL 528

DUAL RANGE 0-3 Amp. and 0-15 Amp. full scale for use on any frequency from 25 to 50 cycles. The ideal instrument for all commercial, industrial, experimental, home, radio, motor and general repair shop testing. Comes complete with a genuine leather, plushlined carrying case and a pair of test leads. A very convenient pocket sized test meter priced at less than 50% of manufacturers list. Your cost ..... **ONLY $12.50**

WESTON MODEL 528 PORTABLE A. C. VOLTMETER

DUAL RANGE 0-15 and 0-150 Volts for use on any frequency from 25 to 125 cycles. Complete with plushlined leather carrying case and a pair of test leads. This Voltmeter, with the matching model Ammeter above, makes an ideal pair of test meters for any mechanic to carry around in his tool box.

ONLY $9.50

COMBINATION OFFER: 528 Voltmeter—528 Ammeter—**BOTH FOR $21.00**

All items are Surplus-New-Guaranteed. C.O.D.'s not sent unless accompanied by 25% Deposit. Orders accepted from rated concerns, public institutions, etc., on open account. We carry a complete line of surplus new meters suitable for every requirement, such as portable, panel, switchboard, recording instruments, laboratory standards, etc. Over 50,000 Meters in Stock. We also stock various surplus components, tubes, parts, and accessories and can supply large quantities for manufacturers, exporters, etc. Send for free circular Manufacturers, Exporters, Dealers—We invite inquries.

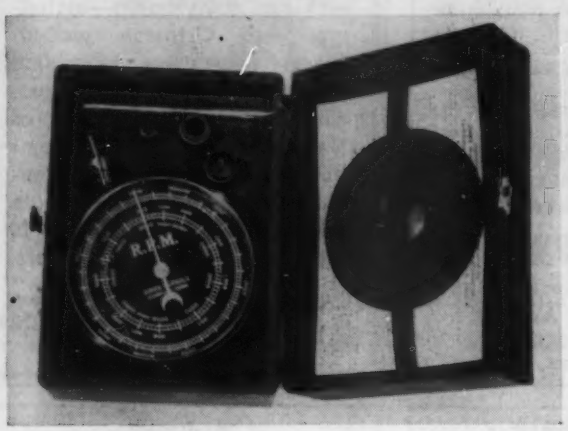
MARITIME SWITCHBOARD

338 Canal Street **Worth 4-8216-7-8-9** **New York 13, New York**

TELL US—TELL OTHERS—SAY YOU SAW IT IN ELECTRONICS!

Multiple Range Continuous Indicating

PORTABLE TACHOMETER



This unit is of the centrifugal mechanical type and is designed to show **INSTANTANEOUSLY and CONTINUOUSLY THE SPEED OR CHANGE IN SPEED** of any revolving shaft or surface. No stop watch or other mechanism required.

- Three ranges in R.P.M., and three ranges in F.P.M.
  Low Range . . 300-1,200 (Each division equals 10 R.P.M.)
  Medium Range 1,000-4,000 (Each division equals 20 R.P.M.)
  High Range 3,000-12,000 (Each division equals 100 R.P.M.)
- Large open dial 4" diameter.
- Ruggedly constructed for heavy duty service.
- Ball bearing and oilless bearings — require no lubricatioan whatsoever.
- Readily portable—Fits neatly into palm of hand.
- Gear shift for selecting low, medium and high ranges.
- Greatest accuracy—neets Navy specifications 18-T-22, Type B, Class A.
- Complete with the following accessories:
  1—Steel tip
  1—Conical Rubber tip metal mounted
  1—Rubber lined metal cone tip
  1—Peripheral Rubber wheel 1 ft. in circumference
  1—Extension Rod
  1—Small size convex rubber tip, metal mounted
  1—Operating Instruction

Made by Jones Motrola, Stamford, Connecticut. Comes complete in blue velvet lined carrying case; 7⅛" L x 4" H x 5" W. **List Price $75.00**—Surplus—New—Guaranteed.

Your Cost $24.50 fob N. Y.

HIGH ALTITUDE ALTIMETER
Radio Set SCR-518

This item consist of a complete set of apparatus for installation on aircraft for use in determining the height above the terrain. The nominal range of the equipment is from 0 to 20,000 feet, but is inoperative to an altitude of approximately 30,000 feet. The complete set of main components when equipped with tubes and fuses, with cable interconnections, with antenna arrays, and primary power source connections, properly made, constitutes a complete and operative equipment. All necessary voltages, other than the primary source, are generated within the equipment. The source of power is an aircraft d-c supply of 24 to 28.6 volts. The total power consumed is approximately 300 watts. Operates at approximately 515 Megacycles.

The set consists of 6 major separate component items. **Receiver, Transmitter, Power unit, Indicator, Control Box & Junction box.**

This equipment comes complete with antennae, connecting cords, brackets, connectors and 29 tubes as supplied by the manufacturer. Brand New—in original cartons. Made by RCA-govt. cost approximately **$900.00**. Complete with OPERATING INSTRUCTIONS & CIRCUIT DIAGRAMS

Can be used, as is, for use as an altimeter, or for adaptation to radar for marine use, protective or police systems, television etc.

The many valuable parts in this set alone are well worth many times this low price of Only **$24.50**

Shipping weight approximately 150 lbs. f.o.b. N. Y.

(For detailed particulars of individual components see our advertisement in the May 1948 issue of "Electronics")

Manufacturers and Exporters!

Can you use these items"

We have quantities of these units available and can offer them to you at attractive prices.

PRECISION RESISTORS

± 1% Accuracy, Wire Wound—Non Inductive

1.0 Meg 1.0 K.V.
1.0 Meg 1.0 K.V.
1.5 Meg 1.5 K.V.
1.5 Meg 1.5 K.V
1.5 Meg 1.5 K.V
2.5 Meg 2.5 K.V.
2.5 Meg 2.5 K.V.
3.5 Meg 3.5 K.V.
4.0 Meg 4.0 K.V.
20.0 Meg 20.0 K.V.
20.0 Meg 20.0 K.V.

TERMINAL BOARDS

4—**Terminal Connections** 3¼" L x 2" W x 1½" H with cover, G.E.
6—**Terminal Connections** 4½" L x 2" W x 1¾" H no cover, G.E.
8—**Terminal Connections** 5½" L x 2" W x 1½" H with cover, G.E.

THERMAL CIRCUIT BREAKER

120 Volt, 15 Amp. A.C. Double pole, Single throw, Curve D. By Heineman Circuit Breaker Co. Catalog #0322.

D. C. MILLIAMMETERS

MINIATURE MILLIAMMETER 1.35 M.A. 500 MV mvt. Black scale calibrated—1 to + 1.25 G.E. 1¾" Square flush metal case.....$2.50
1 MA **Simpson** 125 2½" Rd fl bake case....$3.50
1 MA **G.E.** DW-51 100 MV mvt, sc cal 0.50 Ma 2½" rd fl bake case.....$3.50
50 MA **G.E.** DO-41 black scale, 3⅛" rd fl bake case $3.25
50 MA **Weston** 506 2½" rd fl bake case.....$3.95
150 **Gruen** 508 2½" rd fl bake case.....$3.00
200 **Gruen** 511 2½" rd fl bake case.....$3.00
200 MA **W.H.** NX-35 3½" rd fl bake case...$3.95
50-0-50 MA **Westinghouse** NX-35 3" rd fl bake case $3.95

RADIO FREQUENCY AMMETERS

250 MA **G.E.** Dw-52 black sc, sc cal 0-5 mkd "Antennae Current" 2½" rd fl bake case..$3.50
1 A **G.E.** DW-44 2½" Rd fl bake case.....$3.50
1 A R.F. **G.E.** DW52 2½" metal case.....$3.00
2 A **Simpson** 135 2½" rd fl bake case.....$3.50
3 A **G.E.** DW-52 black scale 2½" rd fl bake case $2.95
4 A **G.E.** DW-44 black scale 2½" rd fl bake case $2.95
6 A **G.E.** DW-44 black scale 2½" rd fl bake case $2.50
8 A **G.E.** DW-44 black scale 2½" rd fl bake case $2.95
8 A **Simpson** 135 2½" rd fl bake case.....$3.50
20 A **G.E.** DO-44 3½" Rd fl bake case.....$4.95

A. C. AMMETERS

30 A—**Triplett** 331-J.P.—3½" Rd fl bake case.$4.00
50 A **G.E.** AO-22 3½" Rd fl bake case.....$4.50
60 **Simpson** 3" sq. fl bake case.....$3.50
75 A **Triplett** 331-J.P.C. 3½" Rd fl bake case $3.50

D. C. AMMETERS

15 A **Triplett** 0321-T 3½" Rd fl bake case...$4.00
30-030 A **G.E.** DW-51 2½" Rd fl metal case..$3.50
50 A **Hoyt** 2½" Rd fl metal case.....$2.95
200 A **Weston** 506 Comp with ext 50 MV shunt 2½" rd fl bake case.....$7.50

D. C. MICROAMMETERS

150 **Microampere McClintock** No. 2001 approx 740 ohms resistance black scale 2½" rd fl bake case $3.50
D.C. MICROAMMETER 0-200 UA movement 500 ohms resistance 4" x 4½" Rectanglar case, knife edge pointer. Scale calibrated to 200 megohms & 20,000 ohms. Caption Insulation Tester. Superior Instruments Co. .....@ $7.50
500 MICROAMPERE UNDAMPED MOVEMENT W.H. RX-35 scale calibrated 0-25 Watts 3" Sq. fl bake case.
Supplied with paper VOMA scale.....$4.95

A. C. VOLTMETERS

15 V. **G.E.** AO-22 3½" Rd fl bake case....$3.95
75 V. **Weston** 517 2" Rd fl ring mounted metal case $2.95
150 V. **Weston** 476 Calibrated for use from 25 to 500 cycles 3½" rd fl bake case.....$6.50
150 V. **Burlington** 32XA 3" Sq. fl bake case..$4.00
300 V. **Weston** 517 2½" rd fl metal case.....$6.00

D. C. VOLTMETERS

5 V **W.H.** NX-33 200 ohms per volt 2½" bake case $3.50
10 V **Sun** 2 AP458 100 ohms per volt 2½" rd fl bake case $2.50
15 V **Gruen,** GW505 2¼" Rd fl bake case....$3.50
20 V **Weston** 506 1000 ohms per volt 2½" Rd fl bake case $3.50
50 V **W.H.** NX-35 200 Ohms per volt 3½" rd fl bake case $3.95
200 V **W.H.** NX-35 200 Ohms per volt 3½" Rd fl bake case $3.95

SPECIAL METERS

Simpson, 25 SIGNAL STRENGTH "S" METER 3½" rd fl bake case. Use this on the plate circuit of your receiver to show the relative strength of incoming signals. Sc. calibrated—6 to 100 DB above 1 microvolt. 5 MA Zero right mvt with translucent sc. for internal sc. illumination from rear of meter. Comp. with socket, lamp and leads. For further details refer to Radio Amateur's Handbook $4.50
DECIBEL METER—Westinghouse RC-35 — 10 to + 6 DB 3" Sq. fl bakelite case 6 M.W. 500 Ohms zero DB = 1.732 volts. Full scale = 3.45 volts $5.95

All items are Surplus-New-Guaranteed. C.O.D.'s not sent unless accompanied by 25% Deposit. Orders accepted from rated concerns, public institutions, etc., on open account. We carry a complete line of surplus new meters suitable for every requirement, such as portable, panel, switchboard, recording instruments, laboratory standards, etc. Over 50,000 Meters in Stock. We also stock various surplus components, tubes, parts, and accessories and can supply large quantities for manufacturers, exporters, etc. Send for free circular Manufacturers, Exporters, Dealers—We invite your inquiries.

MARITIME SWITCHBOARD

338 Canal Street **Worth 4-8216-7-8-9** **New York 13, New York**

TELL US—TELL OTHERS—SAY YOU SAW IT IN ELECTRONICS!

GENERAL ELEC. SOLENOID

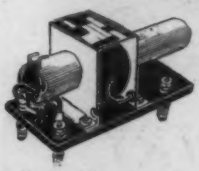
No. R-4242 115 V. 60 Cyc. Type CR 9503-209F Complete with Armature $1.25 each

SPECIALS OF THE MONTH

GENERAL ELEC. SOLENOID

No. R-4243 120 V. 60 Cyc. Type CR 9503-208L Complete with Armature **$1.00 each**

ADLAKE Type 1040-80

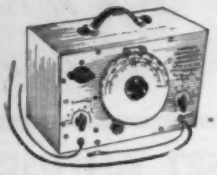


No. R-4012 Mercury Time Delay Relay Normally Opens, Closes in 5 seconds, Opens in .3 seconds. $8.75

SWEEP SIGNAL GENERATOR

McMurdo Silver Co., Model 909 FM and Television Sweep Signal Generator with a frequency range of 2 mc. through 226 mcs, with true electronic FM sweep variable from 40 kc. to 9 mc.

Power required is 105/125 v., 50/60 cycles a.c. at 35 watts, with this new unit one can visually align FM and TV receivers quickly and perfectly with simple but complete instructions supplied for FM and TV servicing.

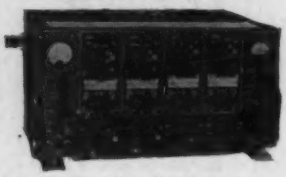


Priced at Only $48.50

TRANSMITTER BUY OF 1948

MODEL ATD AIRCRAFT TRANSMITTER

Built to Rigid Navy Specifications



This unit covers 540 Kc. to 9050 Kc. C W. or fone, designed for Dynamotor Operation. Power supply requirements are 380 volts and 1000 volts DC.

Separate Ant. Tuning units covering the following frequencies:
540—1500 Kc.
1500—3000 Kc.
3000—9050 Kc.

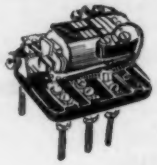
Tube line-up as follows: RF Osc. 6L6-RF Amp. 814—Audio—6SL7 Pre Amp. into 6L6 driver and side tone amplifier with pair of 6L6 modulators, screen oscillator tube, regulated with VR 150 tube. All circuits are metered.
10½" high, 12¼" deep, 21½" long. Shipping weight 100 lbs. Price, F.O.B. New York City.

FOR QUICK SALE—COMPLETE.... **$49.50**

PBC GENERAL ELECTRIC OVERCURRENT RELAY

No. R-4010 Adjustable from 1.5 to 3.0 amperes. 110 volt. 60 cyc. Reset. **$24.95**

WHEELOCK RELAY



No. R-4013 Double Pole Double Throw 115 Volts 60 cyc. Coil 5 amp. contacts. **$2.65**

LAST CHANCE

Going Like "Hot Cakes" At This Greatly Reduced Price New-Standard Brand

304 TL'S

This may be your last opportunity to stock up on spares at this price—and you fellows who plan to build a kilowatt rig in the near future—here is a golden opportunity to still get in on this "all time new low price."

This is a single tube easy to drive for full kw power with 3000 v. plate, actually 4-75 T's in one envelope.

"Filaments checked before shipment"

SPECIAL $1.98

HI-VOLTAGE POWER SUPPLY

Hi & Low Voltage Rectifier Power Supply Model C F T—20169 formerly used with the DAQ Direction Finder. This power supply contains 2500 v. at 3 mils—325 v. at 100 mils. Also contains a sweep amplifier, voltage regulated from 110 v. 60 cy AC. source.

Power Supply can be used to power a television receiver or perfect power supply for an Oscilloscope, or General Lab. use. Unit is mounted in a cabinet with all controls including pilot lights & switches on front panel. Wt. approx. 40 pounds.

$29.95

LIMITED QUALITY

MAGNETIC DEFLECTION YOKES for Television or large scope applications—for use in RCA TRK—120 and similar television receivers

Catalog #	Deflection Angle	Horizontal Inductance	Vertical Inductance	Overall Length
DY-1S	55°	5 mh.	19 mh.	2-5/8"
		Price $14.75		
DY-2L	40°	5 mh.	22 mh.	3-7/16"
		Price $15.75		
DY-4L	40°	1.5 mh.	45 mh.	3-7/16"
		Price $15.75		

FIXED FERRUL TYPE CONDENSER

No. C-2614 Size 5¼" long x ¾" in Diameter. 800 MMF. @ 8 K.V.D.C. **$1.49 each**

MASTER OSCILLATOR MI-19427-B

This unit was built for R.C.A. Add a final—becomes a complete transmitter with signal shifter. Perfect for Television sweep circuits for field or station use or wherever 300 v. must be maintained under varying load conditions—

COMPLETE (less tubes) **$225.00**

TECHNICAL SUMMARY

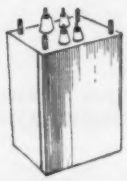
ELECTRICAL CHARACTERISTICS
Output Frequency .....2 to 20 megacycles
Output Lever, Buffer-Amplifier....Sufficient to drive an RCA-807
Modulation Frequency .....650 cycles ± 150 cycles
Frequency Deviation (maximum) .....±500 cycles
Power Consumption .....200 watts
Power Supply .....115 230 volts, 50/60 cycles
Oscillator Filament Current .....0.05 ampere d-c
Amplifier and Tone Generator Filament Voltage.....6.3 volts a-c

TUBE COMPLEMENT
Electron-Coupled Oscillator 2 RCA-3Q5-GT
Buffer-Amplifier 1 RCA-807
Tone Generator 1 RCA-6AB7, 1 RCA-6F6
Regulated Power Supply 2 RCA-5U4-G, RCA-6Y6-G; 1 RCA-1852, 2 RCA-VR-150 30

MECHANICAL SPECIFICATIONS
Dimensions...Height, 66 9 10 in.; Width, 22 in.; Depth, 17⅛ in.

TYPICAL PERFORMANCE DATA — Frequency Change
Line voltage change ± 10 per cent.....0.0005 per cent
Temperature change, per degree Fahrenheit.....0.0007 per cent
Relative humidity change of 1 per cent over the range of 30 to 95 at a dry bulb temperature of 110 degrees F 0.0003 per cent
Drift from cold start, first reading taken within 1 minute after applying power:
Frequency deviation at the end of the first hour a negative drift of 100-400 cycles (measured at 7 mc)

FILAMENT TRANSFORMER—Hermetically sealed 115 v. 60 cyc. primary-sec. #1-6.3 @ 3 amp. sec. #2 2.5 volts @ 2 amps. Western Electric D spec. #161917 insulated for high voltage inverse peaks—designed to light scope tube and 2x2 tube Stock #T4106—5¼" high x 2¾" x 4½" $3.95



SCOPE or TELEVISION TRANSFORMER — Western Electric Spec. #D161913—2500 Volts @ 4 MA. Hermetically sealed with ceramic terminals out bottom. prim. 115 v. 60 cyc. Stock #T4105—5¼" high x 3⅜ x 4½" $6.95

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Type	Price	Type	Price	Type	Price	Type	Price	Type	Price	Type	Price	Type	Price
OA4G	1.06	2V3G	1.10	6F5	.60	7C7	.72	14R7	.88	84/6Z4	.59	872A	1.95
00	.50	2X2	.69	6F6G	.72	7E5/1201	1.06	14W7	1.06	85	.72	874	1.95
OY4	.88	3A4	.72	6F7	.72	7E6	.72	14X7	1.06	89	.72	876	4.95
01-A	.50	3A8GT	1.92	6F7	1.06	7E7	.88	14Y4	.88	99V	1.86	884	.98
OZ4	.88	3AP1	2.95	6F8G	1.06	7EP4	17.95	15AP4	110.00	99X	1.86	902	4.95
1A3	.72	3B7	1.06	6G6G	.88	7F7	.88	15E	1.50	100TH	12.95	920	2.95
1A4	1.28	3B22	4.95	6H6	.60	7F8	1.06	19	1.06	114A	.69	950	1.86
1A4P	1.28	3B23	4.95	6H6GT	.60	7G7	1.06	20	1.56	117L7GT	1.28	954	.49
1A4T	1.28	3B24	1.95	6J4	3.95	7GP4	19.40	20AP4	270.00	117M7GT	1.28	955	.49
1A5G	.88	3B25	.98	6J5	.54	7H7	.88	22	1.28	117N7GT	1.28	956	.75
1A6	1.06	3BP1	2.95	6J5GT	.54	7J7	1.06	23D4	.49	117P7GT	1.28	957	.49
1A7G	.88	3C6	1.28	6J6	1.06	7K7	1.06	23D6	.98	117Z3	.72	958A	.69
1AB5	1.06	3C24	.69	6J7	.72	7L7	.88	24A	.72	117Z6GT	.88	959	.49
1B4	1.28	3D6	.89	6J7GT	.72	7N7	.88	24G	.69	120A	12.95	991	.50
1B5/25S	1.06	3E29	2.95	6J8G	1.06	7Q7	.72	25A6	1.06	121A	2.65	1613	.95
1B7G	.72	3LF4	1.06	6K5GT	.88	7R7	.88	25A7GT	.88	205B	4.50	1614	1.75
1B25A	4.95	3Q4	.72	6K6GT	.54	7S7	1.06	25C6G	1.06	211	4.95	1616	1.39
1B27	4.95	3Q5GT	.88	6K7	.60	7V7	1.06	25L6GT	.59	215A	3.00	1619	.29
1B38	4.95	3S4	.72	6K8	.88	7W7	1.06	25Y5	1.28	217C	7.50	1622	1.75
1C5G	.88	4-65A	14.50	6L5G	.88	7X7	1.06	25Z5	.54	250R	7.95	1624	.98
1C6	1.06	4-125A	27.50	6L6	1.29	7Y4	.72	25Z6	.72	250TH	19.50	1625	.49
1C7G	1.06	4-250A	37.50	6L6G	1.06	7Z4	.72	26	.59	252A	4.95	1626	.49
1D5GT	1.28	5BP1	1.49	6L7	.88	10BP4	34.95	27	.54	259A	4.95	1627	7.95
1D7G	1.06	5BP4	4.95	6N7	.88	10CP4	42.20	28D7	.75	304TL	1.98	1629	.59
1D8GT	1.28	5CP1	3.95	6N7GT	.88	10HP4	49.50	30	.72	307A	6.25	1642	4.95
1E5GP	1.56	5FP7	3.95	6P5GT	.88	10Y	.69	31	.88	310	4.95	1851	1.25
1E7G	1.28	5JP1	9.95	6Q5G	.98	12A6	.89	32	1.06	316A	.89	2050	.89
1F4	.88	5R4GY	1.29	6Q6G/6T7G	1.06	12A7	1.06	32L7GT	1.28	350B	4.95	2051	.49
1F5G	.88	5T4	1.29	6Q7	.72	12A8GT	.72	33	1.06	394A	4.50	5514	3.95
1F6	1.28	5TP4	20.00	6R7	.88	12AH7GT	.88	34	1.06	417A	19.95	5516	5.95
1G4GT	.88	5U4G	.54	6S7	.88	12AT6	.59	35/51	.72	450TL	24.95	5562	10.00
1G6GT	.88	5V4G	.88	6S8GT	.88	12AU6	.72	35A5	.72	531	49.50	7193	.39
1H4G	.72	5W4	.88	6SA7GT	.59	12AU7	.88	35L6GT	.59	701A	4.95	8005	4.95
1H5GT	.60	5X4GT	.60	6SC7	.72	12BA6	.72	35W4	.46	703A	7.50	8011	2.95
1H6G	1.06	5Y3GT	.38	6SD7GT	.72	12BE6	.72	35Y4	.88	705A	2.95	8012	4.95
1J6G	1.06	5Y4G	.50	6SF5	.59	12C8	.89	35Z3	.72	707A	24.95	8016	1.95
1L4	.72	5Z3	.60	6SF7	.72	12DP7	14.95	35Z4GT	.50	709A	9.95	8020	5.95
1LA4	1.06	5Z4	.88	6SG7	.72	12F5GT	.59	35Z5GT	.46	713A	1.65	8025	3.95
1LA6	1.06	6A3	1.06	6SH7	.72	12H6	.59	36	.88	715B	19.95	9001	.89
1LB4	1.06	6A5G	1.56	6SJ7	.59	12J5GT	.54	37	.59	717A	1.65	9002	.49
1LC5	1.06	6A6	.88	6SK7	.59	12J7GT	.72	38	.72	721A	3.95	9003	.49
1LC6	1.06	6A7	.72	6SL7GT	.88	12JP4	60.00	39/44	.59	723AB	5.95	9004	.49
1LE3	1.06	6A8	.72	6SN7GT	.88	12K7GT	.59	41	.59	725A	12.50	9005	.98
1LD5	1.06	6AB5/6N5	.88	6SQ7	.54	12K8	.88	42	.59	750TL	49.50	9006	.49
1LH4	1.06	6AB7	1.06	6SR7	.59	12Q7GT	.59	43	.59	800	2.25	CEQ72	1.95
1LN5	1.06	6AC5GT	.88	6SS7	.72	12SA7	.59	45	.59	801A	1.10	CK1005	.39
1N5G	.88	6AC7	1.06	6ST7	.88	12SC7	.72	45Z5GT	.59	802	2.95	CK1006	.69
1P22	11.50	6AD7G	1.06	6T7	1.06	12SF5	.59	46	.88	803	8.95	EF50	.79
1P5GT	.88	6AF6G	.88	6U5	.72	12SF7	.72	47	.88	805	4.95	EL225	1.95
1Q5GT	.88	6AF8	.88	6U6GT	.72	12SG7	.72	49	.88	807	1.25	FM-1000	1.56
1R4	1.06	6AG5	1.06	6U7G	.59	12SH7	.72	50	1.56	808	2.95	GL434	4.95
1T4	.72	6AG7	1.06	6V6	1.06	12SJ7	.72	50A5	.88	809	1.95	GL446A	2.60
1T5GT	.88	6AJ5	.99	6V6GT	.72	12SK7	.59	50B5	.72	810	7.95	HF100	3.95
1U4	.72	6AK5	.99	6V7G	.72	12SL7GT	.88	50L6GT	.59	811	1.95	HY69	2.95
1U5	.88	6AK6	.88	6W7G	.88	12SN7GT	.88	50X6	.88	812	2.95	HY75	1.25
1-V	.72	6AL5	.72	6X4	.54	12SQ7	.59	50Y6GT	.59	812H	6.90	HY615	1.25
2A3	1.06	6AL7GT	1.06	6X5	.54	12SR7	.72	53	.88	813	5.95	HYE1148	1.25
2A5	.72	6AQ5	.72	6Y6G	.88	12X3	.98	55	.72	814	5.95	RK12	1.95
2A6	.88	6AQ6	.72	6Z7G	1.28	12Z3	.88	56	.59	815	2.50	RK22	4.95
2A7	.88	6AT6	.60	6ZY5G	.72	14A4	1.06	57	.72	826	1.25	RK60	.79
2AP1	2.95	6AU6	.72	7A4	.72	14A5	1.56	58	.72	829B	4.95	RKR72	3.50
2B7	.88	6B4G	1.06	7A5	.72	14A7	.88	59	1.06	830B	5.25	RK73	9.95
2C22	.69	6B6G	.72	7A6	.72	14B6	.88	70L7GT	1.56	832A	2.95	T20	1.95
2C26A	.75	6B7	1.06	7A7	.72	14B7	1.10	71-A	.72	833A	39.50	TZ40	2.95
2C34	.98	6B8	1.06	7A8	.72	14B8	.88	75	.59	836	1.15	V70D	6.90
2C40	2.60	6BA6	.72	7AE7	.72	14C5	.88	75TL	2.95	837	2.50	VR75	.98
2C43	2.60	6BE6	.72	7AF7	.72	14C7	.88	76	.59	838	4.95	VR78	.75
2C44	1.75	6BG6	2.40	7B4	.72	14E6	.72	77	.59	841	.69	VR90	.75
2D21	1.69	6C4	.60	7B5	.72	14E7	.88	78	.59	843	.69	VR105	.75
2E5	.88	6C5	.60	7B7	.72	14F7	.88	79	.88	845	4.95	VR150	.75
2E22	1.50	6C6	.72	7B8	.72	14H7	1.06	80	.42	860	3.00	VT127A	3.00
2E24	4.37	6C8G	1.06	7BP7	2.95	14J7	1.06	81	1.28	861	50.00	VU111	1.50
2E25	3.95	6D4	1.95	7C4	1.06	14N7	1.06	82	.88	864	.69	WE532A	4.95
2E30	2.25	6D6	.60	7C5	.72	14Q7	.88	83	.88	866A	.89	Z225	1.95
2JB51	4.95	6E5	.72	7C6	.72	14S7	1.06	83V	.88	868	1.95		

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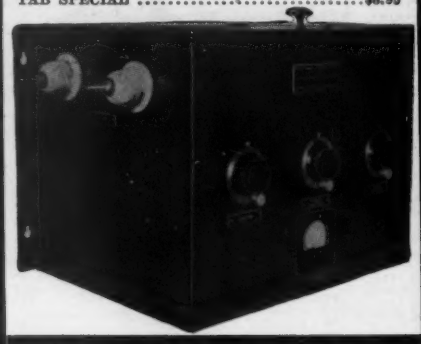

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RECTIFIERS BRIDGE TYPE

INPUT	OUTPUT	CURRENT	PRICE
0–18V	0–14	1.35Amp	$2.25
0–18V	0–14	5Amp	4.85
0–36V	0–28	320ma	1.49
0–36V	0–28	1.1Amp	2.39
0–36V	0–28	1.5Amp	2.89
0–36V	0–28	5Amp	7.50
0–64V	0–54	220ma	3.49
0–64V	0–54	5Amp	16.95
0–90V	0–80	150ma	2.85
0–135V	0–116	3Amp	14.95
0–126V	0–110	150ma	2.95
0–144V	0–125	150ma	2.95
0–350V	0–300	40ma	.85

FULL WAVE CENTER TAP

460VCT	0–110V	1.6Amp	6.95
460VCT	0–110V	220ma	3.49
460VCT	0–110V	3.5Amp	14.95
600VCT	0–250V	2.4Amp	12.95
650VCT	0–272V	150ma	2.95

HALF WAVE TYPES*

0–28V	0–12	150ma	.59
0–72V	0–36	300ma	.98
0–130V	0–100V	100ma	.98
0–216V	0–144	75ma	1.75

*USE WITH CAPACITOR any VDC at 2Xoutput.

CAPACITORS

6000mfd/15WV $2.98; 500mfd/60WV.....$ .98
2000mfd/50WV $1.98; 500mfd/200WV..... 1.49

CAPACITORS OIL RATED WVDC

TAPPED 2.8mfd/200VDC oil.....15 for 1.50
2mfd/330VAC/1000WVDC oil .....5 for 1.98
5mfd/600WVDC/220VAC&Brkts oil .....2 for 1.80
7mfd/600V 99¢; 10mfd/600V 1.39
3.3mfd/225VAC $1.25; 4mfd/600V..... .89
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15mfd/330VAC/1000VDC&2000VDCIntermnt.. 4.50
3mfd/2000VDC $4; 4mfd/3000VDC 5.95
2mfd/2000VDC $2.49; 2mfd/5000VDC..... 10.00
4mfd/5000VDC $16; 2mfd/2500VDC..... 28.00
1mfd/2500VDC $95; 1mfd/4000VDC..... 3.75
.00025mfd/25KV 4.95
2x1mfd/400V 12for$1; 3x1mfd/400V....10 for 1.00
1mfd/400V 12for$1; 2mfd/400V .....5 for 1.00
.5mfd/500V 10for$1; 1mfd/500V .....8 for 1.00
.05mfd/600V 30for$1; 2x.05mfd/600V....25 for 1.00
3x.05mfd/600V 15for$1; 3x.22mfd/600V..12 for 1.00
3x.25mfd/600V 5for$1; .5mfd/600V.....8 for 1.00
3x.1mfd/600V 8for$1; 2x.25mfd/600V....6 for 1.00
.1mfd/1000V 4for$1; .25mfd/1000V.....4 for 1.20
.2mfd/500V $2.25; 1mfd/3600V..... 3.25
.2mfd/5000V $2.25; 1mfd/3600V..... 3.25
VACUUM CONDSRS GE 50MMF/7500V..... 2.95

MICA CONDENSERS RATED

600 WVDC, rated in MFD Capacity

.0001	.00055	.0012	.004		
.0002	.00085	.003	.006		
.00036			.008		
EACH 30¢@.....	10 for $2.50				
.01	@45¢	.026	@92¢	.04	@1.60
.015	@65¢	.03	@1.00	.05	@1.90
.02	@74¢	.039	@1.20		

1200WVDC Rated in MFD Capacity

.0001	@28¢	.004	@64¢	.01	@1.12
.00025	@28¢	.0051	@70¢	.013	@1.20
.001	@36¢	.0062	@70¢	.03	@1.80

2500WVDC Rated in MFD Capacity

00045	@36¢	.0025	@90¢	.005	@1.32
00082	@55¢	.0039	@1.26	.006	@1.38
002	@90¢	.004	@1.26	.01	@1.64
0022	@90¢	.0043	@1.26	.015	@1.78

3000WVDC Rated in MFD Capacity

.00005	@54¢	.0001	@72¢	.0007	@90¢
.005	@1.45				

3500WVDC Rated in MFD Capacity

.C02	@1.00	.003	@1.20

5000WVDC Rated in MFD Capacity

.00003	@2.25	.00025	@2.70	.0015	@2.70
.00009	@2.70	.0005	@2.70	.005	@2.70
.00015	@2.70				

8000WVDC .01MFD @$16.00
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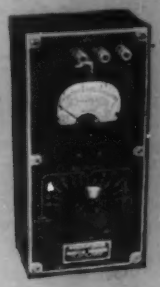
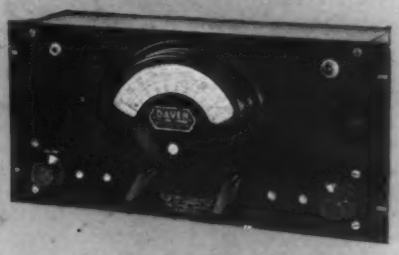


OUTPUT METER



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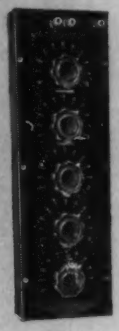

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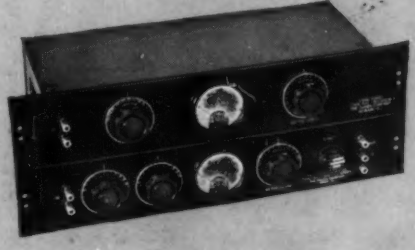

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MATERIALS SECTION

In the following pages, we present a compilation of the properties of materials basic to the manufacture of electronic devices and systems. To our knowledge, it is the first such collection of facts and figures assembled specifically for the electronics field.

Among the classes of materials covered are: acoustic materials, ceramics and glasses, chemicals, coatings, crystals, fluorescent compounds, gases, magnetic materials and other metals, insulating materials and plastics.

It has been impossible to include, in a single issue, all the significant properties of all the materials germane to electronics, but we believe a worthwhile start has been made. We solicit suggestions from readers for additional data to be published in future issues of the Buyers' Guide.

The Editors

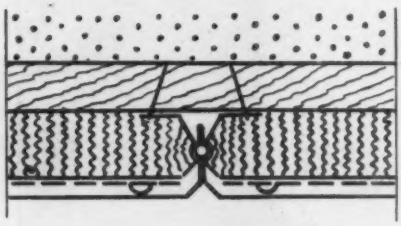
ACOUSTIC MATERIALS . . .

noise reduction coefficients of architectural materials compared with those of some general building surfaces including brick, plaster, tile or wood

Types of Mounting Used in Sound Absorption Test

(1) Cemented to plaster board

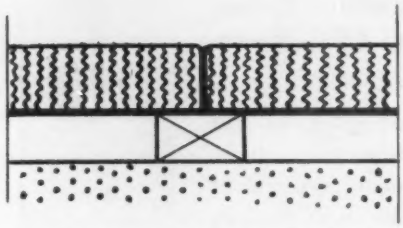
(2) Nailed to 1×2-inch wood furring 12 inches on center



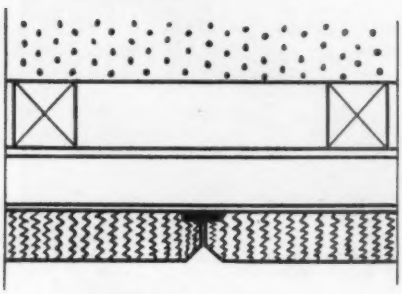
(3) Attached to metal supports applied to 1×2-inch wood furring

(4) Laid directly on laboratory floor

(5) Nailed to 1×3-inch wood furring 24 inches on center and filled in between furring with 1-inch mineral wool



(6) Laid on 24-gage sheet iron nailed to 1×2-inch wood furring 24 inches on center



(Continued on opposite page)

Material	Thickness *in.*	Mounting	Coefficients 128	256	512	1024	2048	4096	Noise Red. Coef.	Wt *Lb* per *Sq Ft*	Surface
Cushiontone[A]											
A-1	½	1	.05	.18	.56	.76	.77	.73	.55	.79	*B*
A-1	½	2	.07	.47	.55	.70	.77	.74	.60	.79	*B*
A-2	⅝	1	.09	.25	.60	.80	.78	.73	.60	.92	*B, AA*
A-2	⅝	2	.13	.45	.55	.73	.79	.75	.65	.92	*B, AA*
A-3	⅞	1	.09	.28	.74	.98	.78	.70	.70	1.17	*B, BB*
A-3	⅞	2	.17	.51	.73	.95	.75	.72	.75	1.17	*B, BB*
Arrestone[A]											
absorbing pads	1¼	3	.25	.56	.99	.99	.77	.60	.85	1.20	*C*
plus metal facing	1⅝										
plus furring	2½										
Mineral Wool Acoustical Mat'l[A]	¾	1	.12	.27	.72	.79	.76	.77	.65	1.13	*CC, DD*
	¾	1	.05	.14	.55	.90	.78	.78	.60	1.13	*D, DD*
Corkoustic[A]											
B-5	1½	1	.06	.16	.73	.69	.56	.89	.55	.77	*C, CC*
B-5	1½	2	.18	.41	.70	.51	.58	.65	.55	.77	*C, CC*
Acousti-Celotex[E]											
type CS-1	½	1	.09	.15	.61	.77	.70	.64	.55	.66	*FG*
type CS-1	½	2	.14	.46	.52	.71	.72	.64	.60	.66	*FG*
type C-4	1¼	1	.14	.42	.99	.74	.60	.50	.70	1.34	*FG*
type C-4	1¼	2	.25	.58	.99	.75	.58	.50	.75	1.34	*FG*
type C-4	1¼	7	.53	.58	.93	.70	.55	.48	.70	1.58	*FG*
type C-6	1¼	1	.15	.34	.99	.94	.61	.61	.70	1.51	*FG*
type C-6	1¼	2	.27	.57	.91	.91	.67	.58	.75	1.51	*FG*
type C-7	1	7	.41	.48	.68	.79	.75	.55	.70	1.40	*FG*
type C-8	1	2	.25	.49	.69	.78	.61	.48	.65	1.54	*FG*
type C-9	¾	1	.11	.23	.80	.93	.58	.50	.65	.96	*FG*
type C-9	¾	2	.12	.45	.79	.89	.61	.60	.70	.96	*FG*
type M-1	⅝	1	.07	.21	.64	.86	.93	.83	.65	1.31	*FG*
type M-1	⅝	2	.12	.48	.50	.79	.93	.82	.70	1.31	*FG*
type M-2	1	1	.08	.27	.92	.95	.80	.71	.75	1.81	*FG*
type M-2	1	7	.40	.44	.79	.99	.77	.71	.75	2.23	*FG*
Muffletone[E]											
standard	1	1	.12	.30	.74	.76	.71	.67	.65	1.80	*EE*
fissured	1	1	.09	.29	.83	.97	.77	.71	.70	1.92	*EE*
Acousteel[E]											
pad	1¼	3	.25	.52	.99	.99	.81	.60	.85	pad 1.08	*K*
plus spacers and metal facing	1⅝										
plus furring	2½										
Sanacoustic[L]											
type MA, pad	1⅛	3	.25	.56	.99	.99	.91	.82	.85	pad 1.25	*M*
plus metal facing and pad supports	1 9/16										

(A) Armstrong Cork Co.
(B) Perforated 484 holes per sq. ft., 1/16 in. diameter, 1/16 in. deep. Painted by manufacturer two coats, face and bevels.
(C) Arrestone is a perforated enameled metal pan, backed with mineral wool sound absorbing pad. Perforations are 0.093 in. diameter, 1105 holes per sq. ft. Bevels and flanges unperforated.
(D) Perforated 484 holes per sq. ft., 3/32 in. diameter, 3/16 in. deep.
(E) Celotex Corp.
(F) Perforated 441 holes per sq. ft., 1/16 in. in diameter, 1/17 in. o.c.
(G) Face painted before perforating.
(H) Painted after perforating.
(I) Perforated 441 holes per sq. ft., 1/4 in. in diameter, 1/17 in. o.c.
(J) Perforated 676 holes per sq. ft., 1/16 in. in diameter, 1/16 in. o.c.
(K) Acousteel is a perforated, enameled metal pan backed with mineral wool sound absorbing pad. Perforations are 0.093 in. diameter, 1105 holes per sq. ft. Bevels and flanges unperforated.
(L) Johns-Manville Sales Corp.
(M) Sanacoustic is a perforated, enameled metal pan backed with mineral wool sound absorbing pad. Perforations are 0.068 in. in diameter, 4608 holes per sq. ft.
(N) One-half perforated enameled metal backed with rock wool pads; one-half enameled metal

Material	Thickness *in.*	Mounting	Coefficients 128	256	512	1024	2048	4096	Noise Red. Coef.	Wt *Lb* per *Sq Ft*	Surface
plus furring	2½										
type KK, pad plus metal facing and pad supports	1¼	3	.25	.58	.96	.97	.85	.72	.85	{pad 1.28}	M
plus furring	1 9/16 2½										
type MA, pad plus metal facing and pad supports	1⅛	3	.22	.70	.63	.67	.52	.48	.65	{pad 1.31}	N
plus furring	1 9/16 2½										
Transite Acoustical Panels[L]											
rock wool blanket plus perforated transite	1	5	.17	.49	.94	.90	.70	.43	.75	1.20	O
	1 3/16										
rock wool blanket plus perforated transite	2	8	.29	.57	.94	.93	.70	.48	.80	2.00	O
	2 3/16										
Transite Acoustical[L] Unit, pad	1	2	.28	.55	.83	.91	.76	.67	.75	2.20	P, DD
	1⅛										
Fibracoustic[L]	1	1	.18	.42	.81	.75	.71	.72	.65	.54	DD
	1	2	.25	.62	.72	.72	.71	.76	.70	.54	DD
Sound Isolation[L]											
blanket MK	1	4	.22	.46	.86	.98	.88	.77	.80	1.20	FF, DD
blanket MK	2	4	.39	.57	.91	.91	.80	.78	.80	2.00	FF, DD
Fibretex[L]	13/16	1	.10	.29	.63	.79	.82	.75	.65	1.04	Q, DD
	13/16	2	.16	.49	.56	.78	.84	.78	.65	1.04	Q, DD
Fibretone[L]	½	1	.09	.23	.52	.58	.58	.68	.50	.71	R, DD
	13/16	1	.14	.37	.69	.80	.76	.73	.65	1.17	S, DD
	13/16	2	.18	.54	.72	.74	.71	.72	.70	1.17	S, DD
Airacoustic[T]	½	6	.13	.41	.40	.72	.78	.72	.60	.80	GG
	1	6	.29	.51	.70	.82	.79	.80	.70	1.50	GG
Acoustex[T]											
type 40R	¾	2	.09	.17	.59	.90	.75	.73	.60	1.71	DD
type 40R	¾	7	.18	.35	.87	.89	.87	.65	.75	1.66	DD
Acoustifibre[T]	⅝	1	.10	.16	.62	.97	.81	.73	.65	.56	U, DD
		2	.13	.38	.72	.89	.82	.66	.70		
Econacoustic[T]	½	1	.05	.17	.62	.83	.77	.74	.60	.40	DD
	½	2	.09	.32	.75	.78	.74	.78	.65	.40	DD
	1	1	.16	.41	.80	.78	.73	.77	.70	.77	DD
Acoustimetal[T]											
type P pad plus spacer and metal facing	1¼	3	.26	.47	.97	.99	.88	.83	.85	{pad .91}	V
plus furring	1 5/8 2½										
Fiberglas Acoustical Tile[W]											
type A	¾	1	.09	.28	.72	.89	.85	.83	.70	.58	DD
type A	¾	2	.15	.30	.79	.95	.83	.79	.70	.58	HH
type A	1	1	.09	.35	.85	.94	.83	.75	.75	.83	H
type A	1	2	.17	.44	.91	.99	.82	.77	.80	.83	
type A	1	9	.67	.67	.82	.89	.91	.98	.80	.75	
Acoustone F[X]	11/16	1	.08	.25	.76	.84	.78	.73	.65	1.35	CC, DD
	13/16	1	.12	.31	.85	.88	.75	.75	.70	1.53	CC, DD
	13/16	7	.38	.64	.62	.68	.76	.75	.70	1.54	CC, DD
Auditone C[X]	¾	1	.09	.28	.68	.80	.79	.81	.65	.91	JJ, DD
	¾	2	.13	.49	.60	.72	.80	.81	.65	.91	JJ, DD
Auditone B[X]	1	1	.13	.33	.79	.85	.85	.72	.70	1.15	JJ, DD
	1	2	.28	.48	.64	.86	.77	.75	.70	1.23	JJ, DD

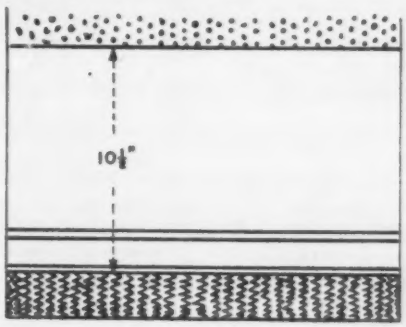
unperforated, unbacked. Perforations 0.068 in. in diameter, 4608 per sq. ft.
(O) Holes are 1/8 in. in diameter, 600 per sq. ft.
(P) Holes are 1/8 in. in diameter, 576 per sq. ft.
(Q) Slotted at 1 in. intervals in two directions to form square pattern. Slots are 1/8 in. wide, 1/4 in. deep.
(R) Holes are 1/8 in. in diameter, 3/16 in. deep; 484 per sq. ft.
(S) Holes are 1/8 in. in diameter, 1/4 in. deep, 484 per sq. ft.
(T) National Gypsum Co.
(U) Acoustifibre is perforated with holes 1/8 in. in diameter, 1/8 in. deep, 441 per sq. ft.
(V) Acoustimetal is a perforated, enameled metal pan backed with sound absorbing mineral wool pad. Perforations are 0.093 in. in diameter, 2016 per sq. ft.
(W) Owens-Corning Fiberglas Corp.
(X) United States Gypsum Co. (AA) Perforations are 1/8 in. deep, (BB) Perforations are 1/4 in. deep, (CC) Fissured, (DD) Painted, (EE) Integrally colored, (FF) Covered with muslin, (GG) Unpainted, (HH) Felted mineral, (II) Fiber surface, (JJ) Slotted.

This information is abridged with permission from a bulletin issued by Acoustical Materials Association. Unit sizes of material tested (not shown here) are often important in determining exact characteristics. Minor differences in coefficients listed are not necessarily of significance.

Types of Mounting (continued)

(7) Attached to special metal supports mounted on 2×2-inch wood furring

(8) Nailed to 2×2-inch wood furring 24 inches on center with 2-inch mineral wool between furring



(9) Mechanically mounted to metal furring strips 24 inches on center 10½ inches from boundary surface of sound chamber

Coefficients of General Building Materials

Material	Coefficients 128	512	2048
Brick wall, painted	.012	.017	.023
Same, unpainted	.024	.03	.049
Carpet, unlined	.09	.20	.27
Same, felt lined	.11	.37	.27
Fabrics, hung straight			
Light, 10 oz per sq yd	.04	.11	.30
Medium, 14 oz per sq yd	.06	.13	.40
Heavy, draped, 18 oz per sq yd	.10	.50	.82
Floors			
Concrete or terrazzo	.01	.015	.02
Wood	.05	.03	.03
Linoleum, asphalt, rubber or cork tile on concrete		.03–.08	
Glass	.035	.027	.02
Marble or glazed tile	.01	.01	.015
Openings			
Stage, depending on furnishings		.25–.75	
Deep balcony, upholstered seats		.50–1.00	
Grills, ventilating		.15–.50	
Plaster, gypsum or lime, smooth finish on tile or brick	.013	.025	.04
Same, on lath	.02	.03	.04
Plaster, gypsum or lime, rough finish on lath	.039	.06	.054
Wood panelling	.08	.06	.06

CERAMICS and GLASS . . .

Ceramic Material	Dielec. Const. 1 mc	Power Factor 1 mc	Dielec. Strength *v/mil*	Resistivity *meg-cm*	Tensile Strength *lb/sq in.*	Compress. Strength *lb/sq in.*	Flexural Strength *lb/sq in.*	Impact Strength *Charpy*	Thermal Expans. *Coeff.*
Alumina (Aluminum Oxide)	4.5–8.4	0.0002–0.01	40–160	10^5–10^8	700–3,000	11,000–60,000	1,500–10,000	0.17–3.0	2.2–7
Aluminum Silicate, Molded	4.8	0.004	100	10^8	2,000	10,000	6,000	2.1	3.5
Aluminum Silicate, Natural Fired Stone	5.3	0.01	80	10^8	2,500	20,000	9,000	3.3	2.9
Cordierite (Magnesium Aluminum Silicate)	4.5–5.4	0.004–0.012	40–250	10^6–10^8	1,000–4,000	20,000–45,000	1,500–8,000	0.2–2.5	1.5–3.0
Forsterite ($2MgO–SiO_2$)	6.2	0.0004	240	10^8	10,000	85,000	20,000	4.0	9.1–10.6
Porcelain, Low-Voltage (Dry Process)	6.0–8.0	0.003–0.02	40–240	10^6–10^8	1,000–3,500	25,000–50,000	3,500–6,000	0.2–2.0	3.0–6.5
Porcelain, High-Voltage (Wet Process)	6.0–7.0	0.006–0.01	90–400	10^6–10^8	3,000–8,000	25,000–70,000	9,000–15,000	0.2–2.2	3.0–6.8
Porcelain, High-Alumina	7.3–11.0	0.001–0.002	100–700	10^8–10^9	8,000–30,000	80,000–250,000	20,000–45,000	0.5–0.7	5.5–8.1
Porcelain, Zircon	7.1–10.5	0.0002–0.008	250–400	10^7–10^9	10,000–15,000	70,000–150,000	20,000–35,000	0.4–1.2	3.0–5.5
Porcelain, Refractory (Mullite)	6.5	0.004	100–300	10^8	1,000–7,500	7,000–85,000	17,000	1.2	1.8–4.8
Steatite (Magnesium Silicate; Talc)	5.5–7.5	0.0002–0.004	200–400	10^7–10^9	7,500–10,000	65,000–130,000	16,000–24,000	0.3–5.0	6.0–10.5
Steatite, Natural Fired Stone (Massive Talc)	5–6	0.0008–0.01	50–100	10^6–10^9	2,000–2,500	20,000–30,000	7,000–9,000	0.2–3.0	8.9–11.5
Titanates	15–5,200	0.0002–0.05	50–300	10^2–10^9	4,000–12,000	40,000–120,000	10,000–22,000	0.3–0.5	6–10
Titanium Dioxide (Rutile; Titania)	14–90	0.0002–0.005	100–210	10^7–10^8	4,000–8,000	80,000–160,000	20,000	1.7–3.1	7–8.7

NOTES

Dielectric properties vary with composition of material and with treatment during the manufacturing process, as well as with conditions under which the material is used, hence specific values should always be obtained from the manufacturer of the chosen ceramic prior to actual design.

In general, the dielectric constant changes only slightly with frequency. Zircon porcelain shows the greatest change, dropping from 7.6 at 1 kc to 6.9 at 100 mc for one grade.

All resistivity values are for room temp. 25C.

Impact strength is given in foot-pounds per square inch as obtained on a ½-inch rod by the Charpy test. Here again manufacturers' data should be consulted for actual values; some values given here were obtained by ASTM test D667-42T and some by D256-43T, while others were not identified as to test procedure.

The coefficient of linear thermal expansion is for the range from 20 to 100C, and is given in

Glass Material	Composition	Density, at 25° C	Coeff. of Therm. Exp. *ppm per °C*	Softening Point, *°C*	Anneal. Temp., *°C*
Quartz, fused, clear[4]	Silicon dioxide	2.20	—	1,667	1,140
Corning Glass No. 001	Soda-potash-lead-silicate	2.85	9	626	425
Corning Glass No. 008	Soda-lime-silicate	2.47	9.2	634	463
Corning Glass No. 009	Potash-lead-silicate	4.13	6.9	630	431
Corning Glass No. 010	Potash-soda-barium-silicate	2.82	9.2	696	510
Corning Glass No. 012	Soda-potash-lead-silicate	3.05	8.7	692	527
Corning Glass No. 171	Lime-alumina-silicate nearly alkali free	2.53	4.1	925	716
Corning Glass No. 704	Soda-potash-borosilicate	2.24	4.9	697	484
Corning Glass No. 705	Soda-borosilicate	2.23	4.6	1,160	750
Corning Glass No. 706	Soda-borosilicate	2.25	5.0	693	494
Corning Glass No. 707	Low alkali, potash-lithia-borosilicate	2.13	3.1	819	553
Corning Glass No. 723	Aluminum borosilicate	—	1.4	703	496
Corning Glass No. 772	Soda-lead-borosilicate	2.35	3.6	756	526
Corning Glass No. 774	Soda-borosilicate	2.25	3.3	746	490
Corning Glass No. 775	Soda-borosilicate. Higher content of B_2O_3 than No. 705	2.20	4.2	701	467
Corning Glass No. 790	96 percent SiO_2	2.18	8	1,450	930
Corning Glass No. 3320	Sodium-potash-borosilicate	2.29	4.1	710	481
Corning Glass No. 7052	Soda-potash-lithia-borosilicate; relatively high Al_2O_3	2.31	4.7	788	536

(4) Quartz has compressive strength of 190,000 lb per sq in.; tensile strength of 7,000 lb per sq in.; electrical strength at 25 C of 15,000 volts per mil; and surface resistivity at 50 percent humidity between 2 and 5 × 10^6 ohms.

electrical porcelains, steatites, titanates, fused quartz and glass

Te Value °C	Safe Temp. °C	Water Absorp. %	Spec. Grav.	Remarks
400–835	1,300–1,600	0.00–20	2.2–3.2	Extremely hard (Mohs 9.0). Easily degassed. Used for insulation in vacuum tubes, for spark plug cores, thermocouple insulators and vacuum insulators.
645	1,350	10–15	2.1	Highly refractory body with good electrical properties.
620	1,100	2.5	2.3	Commonly known as Lava. Insulators are machined from the natural block, then fired. Shrinkage in firing is low. For small production runs.
400–780	1,200–1,250	0.5–15	1.6–2.3	Highly resistant to heat shock. For resistor and coil forms and supports, arc chambers, burner tips, heat insulation and thermocouple insulators.
1,000	1,000	0.00–0.05	2.8	Similar to steatite. Low loss factor; very dense; high and uniform coeff. of expansion between 20 and 700C, easily matched by a nickel-iron alloy.
275–400	900	0.5–2	2.2–2.5	For switch bases, resistor forms, lamp sockets, and low-voltage insulators. Glazing improves appearance, reduces water absorption, makes cleaning easier.
300–500	1,000	0.00–0.5	2.3–2.5	For power-line insulators, resistor forms, and terminal blocks. All porcelains can be glazed at very little increased cost.
700	1,350–1,500	0.00	3.1–3.9	For spark plug cores, thermocouple insulation, and protective tubing for high-voltage wiring. All porcelains can be machined by grinding.
700	1,000–1,200	0.00–0.5	3.0–3.8	Power factor drops at high frequencies, giving low loss factor. Zircon improves heat shock resistance. For coaxial cable insulators, etc.
600	1,000	0.00–10	2.3–2.8	Provides heat resistance at low cost for insulation and mechanical supports as in heating elements. All electrical porcelains are chemically inert.
440–1,000	980–1,100	0.00–0.05	2.5–2.8	For casting, wet or dry pressing, extrusion and machining. Used for high-frequency insulation and for insulation in electrical appliances.
600–900	1,200	1–3	2.3–2.8	Commonly known as Lava. Objects are machined from the natural block and fired. For spacers in vacuum tubes and for high-frequency insulation.
200–400	800–1,000	0.00	3.1–8.9	For dielectric material in ceramic capacitors and for lightning-arrester insulation. Properties of the various titanates vary greatly with composition and manufacturing processes. Barium titanate with K of 1,200 was used for capacitor dielectrics in proximity fuze. Temp. coeff. of cap. is zero for K of 20 with TiO_2, is positive under 20, and negative over 20.
550	1,000	0.00	3.9–7.2	

inches per inch per degree C $\times 10^{-6}$ (multiply values in this column by 10^{-6}).

The Te value is the temperature in degrees C at which a 1-centimeter cube has a resistance of one megohm. This is a convenient method for comparison of volume resistivity at elevated temperatures, since ceramic dielectric materials decrease their volume resistivity as temperature goes up (negative temperature coefficient of resistance).

Hardness of ceramics ranges from 6 to 9 on the Mohs scale, wherein the specimen is rubbed against sample minerals of varying hardness, each identified with a number.

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Vol. Resist. 350° C, *ohms*	Dielec. Const., 100 mc	Loss Tangent[B] 100 mc	Remarks
3×10^{10}	3.85	0.0001	High quality insulator.
1.33×10^{7}	6.37	0.0024	High expansion, high resistance glass.
1.20×10^{10}	9.0	0.0022	Used for X-ray shields.
9.55×10^{7}	6.65	0.0018	Lead-containing glass with high expansion and high resistance.
1.48×10^{5}	6.75	0.008	Bulbs, bottles, and windows.
3.98×10^{8}	7.06	0.0028	High expansion, high resistance.
2.85×10^{9}	6.0	0.0042	High temperature, low expansion, high resistance applications.
8.80×10^{7}	4.65	0.0028	Used for sealing to metals.
———	3.8	0.0016	Used for small tungsten seals and sealing to silica.
2.57×10^{6}	4.7	0.004	Seals to metal and glasses.
4.73×10^{6}	5.0	0.008	General low-expansion glass. (Pyrex brand chemical glass).
5.89×10^{6}	4.75	0.0034	Sealing to metals and glasses.
1.59×10^{7}	4.5	0.0032	Tungsten sealing.
1.30×10^{9}	4.0	0.0012	Low loss glass.
5.31×10^{7}	4.3	0.0024	Intermediate glass sealing.
1.29×10^{8}	3.9	0.0006	High temperature, low-loss, low-expansion glass.
2×10^{7}	5.0	0.0036	Seals to metals.
1.14×10^{7}	4.7	0.0042	Tungsten sealing, intermediate glass sealing.

(B) Loss tangent equals loss factor divided by real dielectric constant.

CHEMICALS . . . *a brief list of materials*

ACETONE (acetone oil)—Colorless liquid from about —95 C (melting point) to 56 C (boiling point), solvent for insulating compositions containing natural or synthetic resins, cellulose esters or ethers, plastics, lacquers, and varnishes; commercial grade is practically pure.

ADHESIVES—Used in joining various types of materials to each other, adhesives are made in great variety. Styrene resin synthetic thermoplastic adhesives bond by releasing their solvent, which is an aromatic hydrocarbon, and are fused by heating. They are resistant to water and fungus and, although mechanically brittle, are good electrically. Vinyl acetal, with alcohols or fatty acid esters as solvents, are cured by releasing the solvent under heat; it is an excellent adhesive for glass and resists fungus. One of the best adhesives for metals is phenolic-elastomer, a synthetic thermosetting resin. It is cured at from 275 to 310 F; solvents are chlorinated hydrocarbons and ketones.

ALUMINUM CHLORIDE—Catalyst in making dielectrics from polyphenyl derivatives of methane and ethane, halogenated in an aromatic nucleus, and derivatives of benzophenone; such dielectrics tend to be chemically stable under all conditions encountered in electrical applications and tend not to produce explosive gases when subjected to arcing.

ALUMINUM METAPHOSPHATE—White powder used as constituent of glazes, enamels, glasses, and as a high-temperature insulating cement.

ALUMINUM OXIDE—White crystalline artificial corundum used as abrasive in different grades for toolroom grinding, abrasive wheels, papers, cloths, and, mixed with oils, as grinding compounds. Because of its high melting point (3,720 F) it is used as a refractory, and as a high-grade insulator.

ALUMINUM SILICATES—Clays consist of aluminum silicates in varying degrees of purity, usually containing quartz, mica, iron, lime, magnesia, and alkalies. Most domestic clays are kaolins (China clays) consisting chiefly of hydrated aluminum silicates, used for electrical insulation. Mica is a class of aluminum silicates and an alkali such as potassium, sodium, or lithium; iron, magnesium, and chromium are usually present so that the color varies from transparent to green, red brown, gray, or black. The naturally occurring thin, slightly elastic sheets are used directly or the mica is ground into a binder to form electrical insulators.

ALUMINUM SULFATE—White powder extremely soluble in water forming an acid solution, used in storage battery electrolytes for which the iron-free grade is used; ammonium alum (sulfate) is similarly used, especially for lead-plate storage batteries.

AMBER—A yellow or brown translucent fossil resin found in alluvial soils or with beds of lignite; it takes a fine polish (and becomes electrified). Fine varnishes are made with amber as a base.

AMMONIUM BORATE—Acid salt soluble in water giving a slightly alkaline solution, used as capacitor electrolyte.

AMMONIUM CHLORIDE—Commonly called sal ammoniac, it is a white but discolored granular material that is very soluble even in cold water, slightly soluble in alcohol; it is used as soldering flux or as electrolyte in dry cells, as is the double salt zinc ammonium chloride, and ammonium sulfate.

AMMONIUM SULPHATE—Salt, extremely soluble in water, used as a flux for soldering and galvanizing iron.

AMYLOLAMINE—Dispersive agent in making special lubricants for electrical switches.

ANILINE (aniline oil)—Colorless oil turning red or brown in air; solvent for tungsten hexachloride in making tungsten filaments.

BARIUM SULFATE—Occurring naturally or commercially ground, it is called barytes; process material in making arc electrodes, insulators, resistances, storage battery electrodes or separators.

BEESWAX—Yellow or bleached grades are ingredients of insulations, paints, varnishes, fillers in making rubber insulators, electroplater's wax.

BENZENE—Colorless, volatile, inflammable, toxic liquid boiling from 80 to 120 C, used as a solvent or diluent for waxes, resins, and rubber in manufacturing insulations for cables, wires, and coating electrical equipment.

BORAX (sodium borate)—Alkaline salt slightly soluble in cold water, highly soluble in hot water, used as flux with solders, ingredient in electrolytes for rectifiers, capacitors, and lightning arresters.

BORON CARBIDE—Black, crystalline powder of great hardness used as an abrasive, cutting compound for molded insulations, electrode and terminal materials, and compressed into dies for drawing wire. Commercial grades contain graphite as a lubricant.

CARBONDIOXIDE—Colorless, odorless gas, soluble in water, used as reagent in fire extinguishers for electrical equipment, maintaining an inert atmosphere in oil-filled

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A more extensive listing of chemicals used in all industries will be found in "Uses and Applications of Chemicals and Related Materials", T. C. Gregory, Reinhold Publ. Co. and in "Chemicals of Commerce", F. D. Snell and C. T. Snell, D. Van Nostrand Co.; properties of many chemicals are given in "Handbook of Chemistry and Physics" edited by C. D. Hodgman, Chemical Rubber Publ. Co.

transformers to prevent possible combustion of the oil, and for testing the tightness of cable and waveguide joints. In the solid form (dry ice), it is used to cool vacuum traps in evacuating systems.

CARBON TETRACHLORIDE—Solvent for esters or ethers of cellulose, resins, and gums, used in or as solvent for insulations made of such materials, also as a substitute for oil in electrical switches and transformers requiring high insulation resistance.

CARNAUBA WAX—Crude greenish brown wax occurring naturally on leaves of a Brazilian palm tree; it is refined with sulfuric acid to give a yellow product. It solidifies at from 80 to 87 C and is soluble in boiling alcohol, hot turpentine, or carbon tetrachloride. The hardest of the waxes, it is used in insulating compounds and phonograph records.

CERESIN—Noncrystalline wax-like material containing paraffin and other waxes; commercial varieties melt at from 140 to 180 F; used as general insulating agent, binder, coating material; used as insulation in capacitors, boiling out agent for cables, machines, transformers, coating and insulation for batteries, radio wires and coils, filler for cable junctions, sealing agent for dry electrolytic cells, waterproofing for instruments and machinery, and ingredient of other insulating compositions.

CERESINE—White or yellow wax made by purifying ozokerite; it is used as a substitute for beeswax. Ozokerite is a waxlike mineral, colorless or white when pure but often greenish, yellowish, or brownish; it is a mixture of hydrocarbons, also called ader wax, and used in taking impressions to be electroplated. It occurs naturally or is made synthetically.

CONDUCTIVE COATING—Mechanized wiring methods, in which a high-conductivity material is applied to a nonconductive material, use various grades of conductive, coatings. For bonding metals to ceramic bases, a coating consisting primarily of silver powder and finely ground low-melting glass in a liquid vehicle and with an organic binder is used. After the binder is burned out by firing, this coating gives a very high conductivity. The coating can be applied to glass, porcelain, steatite, plastics, wood, cloth, paper, and metals. Applied to metals, the coating inhibits rust of the base thus preserving its surface conductance. The coatings can also serve as a base for subsequent electroplating, in which case a thin layer of copper is first electroplated over the coating, after which any other metal can be plated on. The conductive coatings can be applied by spraying, dipping, brushing or stenciling. One troy ounce of materials covers about three square feet of surface.

COPPER SULFATE—Also called cupric sulfate, blue vitriol, or bluestone, this most common of all salts of copper is an ingredient of battery electrolytes and electrolytes used in making masters for pressing phonograph record discs.

DIAMYLAMMONIUM DIHYDROGEN PHOSPHATE—Hard, yellow gum used as a constituent of rust-inhibiting paints.

DICYCLOHEXYL—Clear liquid used as a high boiling point solvent, plasticizer, and dielectric.

GLASS-BONDED MICA—Finely powdered mica, usually muscovite or occasionally phlogopite, is bound in a low-melting glass, usually of the borate or borosilicate type with or without lead. The mixture is solidified at high temperature and pressure. Because the mica, even in its finely ground state, is in the form of flat plates, it orientates itself across the direction of pressure during formation so that the finished product has directional properties. The glass-bonded mica can be machined most simply across the grain; tungsten carbide tools and water as a coolant and lubricant are used. If the surface is smooth, glass-bonded mica does not absorb water or oil, has a higher softening temperature and lower coefficient of expansion than plastics. Semipolished glass-bonded mica can have a loss factor as low as 0.014 at one megacycle; its dielectric constant is practically independent of frequency from 50 kilocycles to 10 megacycles and lies between 6.5 and 11 depending on composition; dielectric strength is 500 volts per mil; surface resistance (after four days at 85 F and 85 percent relative humidity) is 300,000 megohms per inch. Glass-bonded micas are used as tube bases, coil forms, and other structural and insulating parts requiring dimensional stability and good high-frequency properties.

IODINE—Ingredient of fluorescent screens containing calcium tungstate and an inorganic binder, and in selenium photocells.

ISOPROPYL ALCOHOL—Solvent for shellac in making capacitors, cements for tube bases and caps, damp-proofing insulating coatings for coils, and for insulators and seals.

MALIC ACID—Ingredient of electrolyte for capacitors and lightning arresters; it is a colorless crystalline solid that is soluble in water, alcohol, or ether.

MANGANESE CHLORIDE—A process material used in making depolarizers for dry batteries and a substitute for sal ammoniac in charging electric batteries; mercuric chloride and manganese dioxide are also used as depolarizers in batteries.

MANNITOL—Ingredient of paste used in making dry electrolytic capacitors.

MERCURIC OXIDE—Both red and yellow mercuric oxide are used as depolarizers in mixture with graphite in batteries containing manganese dioxide and sulphuric acid.

MERCURY—The only metallic element that is liquid at normal temperatures; solidifies at —40 F, boils at 662 F, does not oxidize at normal temperatures; it is used in rectifiers and switches, as a bath in sealing glass bulbs and in vacuum pumps, as an ingredient in electrolytes, and otherwise in batteries. Mercury bisulphate is an ingredient of the active agent in batteries.

METHYLOLAMINE—Dispersive agent used in making special lubricants for electric switches.

MOLYBDENUM TRIOXIDE—Reagent used in making filaments.

PHOSPHORIC ACID—Ingredient or process material for electrolytes for rectifiers, capacitors, batteries, and for resistances and filaments.

SILICONES—Organosilicon polymers have a wide range of physical properties. Organosilicon fluids have high temperature stability and other properties that suit them for use as lubricants under adverse conditions, mold release fluids, and diffusion pump fluids (without cold traps a vacuum of 1×10^{-7} mm of mercury can be obtained). Silicone greases provide lubricants that do not harden to temperatures as low as —95 F or that melt to as high as 500 F; they can be used in high-vacuum seals operating at vacuum less than 10^{-6} mm of mercury, or as dielectrics. Insulating varnishes made from silicones are heat and moisture resistant, and have dielectric strengths (volts per mil, 0.25-in. electrode) from 2,000 (wet) to 3,000 (dry), dielectric constant at 1,000 cps of from 3.0 to 3.5 and a power factor of approximately 0.7 percent. Silicone resins used directly for insulating magnet wire have low moisture absorption, and used for bonding or impregnating laminates impart high insulation resistance and dielectric strength. Fibrous glass laminates bonded with a thermosetting silicone resin have a dielectric strength of 270 volts per mil, a dielectric constant of 3.7, which increases to 4.73 after 24 hours immersion, and a power factor of 0.0051, which increases to 0.0125 after 24 hours immersion, both at one megacycle. The insulation resistance is greater than 100,000 megohms. The silicone resins also provide protective coatings. Silicone elastomers (Silastic), being 90 percent inorganic, retain their rubbery properties from —56 C to over 260 C. The bond energy between the silicone and oxygen atoms of the molecular skeleton of the silicone elastomers is about 89 kilocalories per mol while the bond energy between carbon atoms of the skeleton of synthetic and natural rubbers is only about 59 kilocalories per mol. Silastics have dielectric constants ranging from about 3 to 11 and power factors from 0.1 to 6.0 percent at one megacycle, and a surface resistivity of the order of 10 million megohms. Among the applications for silicones, aside from those directly related to its use as an insulating material, are as a resin binder in producing heat stable and waterproof basing cements for sealing transmitting tubes to metal bases, as a bond for powdered metals, silica, asbestos, glass, or mica, or for carbon in the fabrication of electrical resistors, as a corona and moisture resistant filler for sealing high-voltage terminals, as a water repellant for coating ceramics, as a lubricant when passing electrical cables through close-fitting spaces, and as a moisture-proof seal for radar and other microwave systems.

SODIUM CYANIDE—White crystalline powder, soluble in water and very unstable; on exposure to moist air it liberates highly poisonous hydrocyanic acid gas. Combines with metals to form soluble double salts. Used as electroplating bath for gold and silver.

SODIUM SILICATE—High-temperature insulators, ingredient of electrolyte for rectifiers.

SORBITOL—Humectant in dry-type electrolytic capacitors.

SULFURIC ACID—The most widely used acid, used for cleaning, as a solvent, and process material in numerous ways. Battery acid, a grade of sulfuric acid especially purified for use in lead-plate storage batteries, is colorless and practically free from iron impurities. Commercial concentrations range from 1.200 to 1.835 specific gravity. Other grades of sulfuric acid are variously purified and concentrated depending on intended use.

THALLIUM OXYSULPHIDE—Light-sensitive material in photocells; tellurium is used in making crystal detectors and dry rectifiers.

TIN TETRACHLORIDE—Starting point in depositing oxide coatings on filaments of thermionic, x-ray, and rectifier tubes.

TRANSFORMER OIL—Practically nonvolatile grade of mineral distillate, free from water and acids, used as a cooling and insulating agent.

VARNISHES—Numerous types and grades of varnish coating materials are used to provide protection from oil and moisture and electrical insulation. Of the solvent type varnishes, synthetic phenolics either unmodified or oil modified produce hard brittle films, cure by heat giving off water and in some cases ammonia during polymerization. Once cured they are dimensionally stable and thermoset (will not soften on reheating). Bases for such varnishes are phenolformaldehyde, phenolfurfural and cresylformaldehyde reaction products; solvents such as alcohol, ketone and benzol solvents are used. Such drying oils as tung oil, linseed oil and dehydrated castor oil are used to modify this type varnish. They make the varnish film more plastic and flexible; the varnish then cures by heat or oxidation of the drying oil giving a tougher, less brittle film than the unmodified phenolic varnishes. Alkyd varnishes are various formulations of polyhydic alcohols and polybasic acids; combined with drying oils they form baking or air-drying varnishes that give tough, elastic, moistureproof films. Alkyd resins combined with drying oils form varnishes that are cured by heating in air; only thin films can be laid down as thick ones will not cure in their cores. They form tough, plastic, flexible, heat resistant and moisture-proof films. The varnish can be pigmented with fillers to increase its resistance to moisture and arcing. Included in this class are also maleic anhydride unsaturated resins which form slightly hard films that are very resistant to moisture and heat, oil modified oxidizing alkyds that form soft films, alkydphenolic resins and natural resin modified by alkyds. Oleoresinous natural resin varnishes are mixtures of natural or reacted gums modified with drying oils in solvents. They cure by reaction with oxygen during heating and are not fully thermosetting. They form hard, tough, moisture-resistant thin films. Those made with asphalts with drying oils in solutions of pitch or gilsonite and drying oil in a solvent such as petroleum naphtha form soft plastic films cured by heating in air; they soften on reheating above about 100 C. Varnishes made with silicones (which see) are best for applications requiring resistance to high temperature.

ZINC CHLORIDE—White, crystalline, poisonous substance used as soldering flux, dehydrating agent, wood preservative, and as a constituent of adhesives.

ZIRCONIUM OXIDE—Also termed zirconia, it is a white crystalline powder having a melting point of 5,350 F when pure; it is the most heat resistant of the commercial refractories, the commercial product melting at about 5,000 F, and having the very low coefficient of expansion of 0.0000008; it resists acids and alkalies. It is used as an incandescent body in lamps, and in compositions used for insulation. The oxide is the chief source of the metal, which is used as a getter for oxygen and nitrogen, or is heated with carbon to form zirconium carbide which is a very hard abrasive.

GASES... physical properties of inorganic gases, principal spectral lines of ionized gases, and characteristics of gaseous insulators

Inorganic Gas	Molecular Weight	Density at 0° C 760 mm Hg *gm/liter*	Thermal Conductivity at 0° C *cal/cm/sec/deg C×10⁻⁶*	Specific Heat at Constant Pressure *cal/gm/deg C*	Velocity of Sound at 0° C *meters per sec*	Resonance[a] Potential *volts*	Ionizing Potentials[b] *volts* I	II	III	Wavelengths of Principal Spectral Lines *angstrom units*	
Air, dry	——	1.2929	56.8	0.2374	331.7	——	——	——	——	——	——
Argon	39.94	1.782	40.6	0.1252	——	11.56	15.69	27.8	36.8	1,048.26	1,066.70
										6,965.430	7,067.217
										7,503.867	8,115.311
Helium	4.00	0.1785	336.3	1.251	——	20.91	24.5	54.1	——	584.4	3,888.646
										5,875.618	
Hydrogen	2.02	0.0899	327	3.389	1,269.5	10.2	13.5	——	——	1,215.7	4,861.327
										6,562.79	
Krypton	83.70	3.708	21.2	0.0597	——	9.98	13.94	26.4	31.2	5,570.290	5,870.916
Mercury Vapor	200.61	——	——	——	——	4.87	10.38	18.7	——	1,849.68	2,536.519
										3,650.146	3,654.833
										3,663.276	4,046.561
										4,358.35	5,460.740
Neon	20.18	0.9002	109.2	0.2455	——	16.58	21.47	40.9	63.2	735.95	743.73
										5,400.562	5,832.488
										5,852.488	6,402.246
Nitrogen	28.04	1.2506	52.4	0.2447	——	6.3	14.48	29.5	47.4	1,199.5	1,200.2
										4,099.94	4,109.98
Oxygen	32.00	1.4290	56.3	0.2178	317.2	9.11	13.55	34.9	54.9	1,302.27	1,304.96
										1,306.12	7,771.928
										7,774.138	7,775.433
Sodium Vapor	23.00	——	——	——	——	2.1	5.12	47.5	70.8	3,302.323	3,302.988
										5,682.657	5,688.224
										5,889.953	5,895.923
Xenon	131.30	5.851	12.4	0.0382	——	8.39	12.08	21.1	28.5	1,295.8	1,469.9
										4,500.977	4,624.276
										4,671.226	

[a] Resonance potential represents the energy a bombarding electron must have to impart the next higher energy level to the outer electron of a gas atom.

[b] Ionizing potentials I, II and III represent the energy bombarding electrons must have to remove completely successive outer electrons of a gas atom.

Insulating Gas[a]	Relative Dielectric Strength[b] for D-C	Boiling Point *deg C*	Microwave Absorption Coefficients[c] 9,430 mc	24,200 mc	Dielectric Constants 9,430 mc	24,200 mc	Remarks
Trichloromonofluoromethane CCl_3F	3.0	24.1	——	——	——	——	Freon 11. Vapor-nitrogen mixture
Dichlorotetrafluoroethane $C_2Cl_2F_4$	2.8[d]	3.8	——	——	——	——	Freon 114
Trichlorotrifluoroethane $C_2Cl_3F_3$	2.6	47.2	——	——	——	——	Freon 113. Vapor-nitrogen mixture
Dichlorodifluoromethane CCl_2F_2	2.4[e]	−28.0	0.00003	0.00031	1.00029	1.00031	Freon 12
Sulfur Dioxide SO_2	1.9	−10.0	0.00011	0.00050	1.00075	1.00086	Corrosive when wet
Carbon Tetrachloride CCl_4	1.65[f]	76.74	——	——	——	——	Nonflammable. Toxic. Data given for vapor-nitrogen mixture
Dichlorofluoromethane $CHCl_2F$	1.33	14.5	0.00052	0.00106	1.00049	1.00052	Freon 22
Hydrogen Sulfide H_2S	1.30	−60.75	≦0	≦0.00003	1.00030	1.00035	Toxic. Corrosive when wet
Ethylamine $C_2H_5NH_2$	1.06	16.51	0.00031	0.00102	1.00053	1.00045	Flammable
Methyl Chloride CH_3Cl	1.06	−24.4	0.00055	0.00080	1.00094	1.00099	Moderately flammable
Dimethylamine $(CH_3)_2NH$	1.04	7.4	——	0.00070	——	1.00040	Irritating. Flammable
Methyl Bromide CH_3Br	1.02	3.7	0.00042	0.00062	1.00095	1.00100	Nonflammable. Toxic

[a] Measurements were made at 23° C and 760 mm mercury total pressure. Complete data on behavior of gases at microwave frequencies, including variation in complex dielectric constant and changes in dielectric strength with amplitude, duration, duty cycle and frequency of pulsed r-f power, are not yet available.

[b] Dielectric strengths are given relative to that of nitrogen at room temperature and 760 mm mercury pressure (E. E. Charlton and F. S. Cooper, Dielectric Strength of Insulating Fluids, *General Electric Review*, p 438, September 1937).

[c] Reciprocal of absorption coefficient is path length in cm at which power in a plane wave will be reduced to 1/e of its initial value (John E. Walter and W. D. Hershberger, Absorption of Microwaves by Gases, *Journal of Applied Physics*, p 814, October 1946).

[d] Relative dielectric strength increases to 5.6 at a vapor pressure of 2 atmospheres absolute.

[e] Relative dielectric strength increases to 15.3 at a vapor pressure of 6.05 atmospheres absolute.

[f] Relative dielectric strength increases to 3.2 at a vapor pressure of 1 atmosphere absolute and a temperature of 80° C.

chromized steel is somewhat similar to that of high-chromium steels.

COPPERWELD—Process of producing surface layer of copper on steel to improve corrosion resistance and increase electrical conductivity, involving pouring of molten copper around a heated steel billet fastened in the center of a mold. The composite ingot is then rolled and cold drawn to the desired size and cross-sectional shape for wire, bars, nails, ground rods, etc. On wire, the thickness of the Copperweld coating is 10 to 12.5% of the wire radius.

CORRONIZING—A process in which nickel is plated on steel, followed by a layer of zinc. The composite coating is heated to a temperature at which the zinc and nickel form an alloy. The two metals may also be codeposited.

CREOSOTE—A distillate of coal tar used extensively for wood preservation. Sometimes used in solution with coal tar or petroleum to seal pores of wood. Surface cannot be painted.

ELECTROGALVANIZING—A method of applying a protective zinc coating to steel by immersing the parts in an electrolyte of cyanide zinc or a sulfate of zinc and passing a current from the sides of the tank or from electrodes to the work. Preliminary cleaning is highly essential. Aluminum powder is sometimes spread over the zinc bath during galvanizing to prevent oxidization of the zinc and produce a silvery finish.

ELECTROPLATING—Used for applying protective coatings of brass, cadmium, cobalt, chromium, copper, nickel and zinc to iron and steel. Only cadmium, chromium and zinc afford protection because they are electronegative to iron; the other metals are used because of their own good corrosion-resisting properties and because they are good surface finishes.

ELECTROPOLISHING—Method of finishing silver-plated objects that is essentially reverse electroplating. The work is made the anode after electroplating and current is passed until approximately 2% of the silver deposit has been removed. Resulting luster is equal to that obtained by removing 5 to 10% by hand buffing. The electropolishing electrolyte is an alkaline cyanide solution composed roughly of 5 oz Troy silver per gal, 4.5 oz Avoir potassium cyanide per gal, and 7 oz potassium carbonate per gal. Voltage is about 5 volts d-c and polishing time is about 15 seconds.

ENAMEL—Pigmented varnish; essentially a mixture of opaque with a nonvolatile vehicle and a volatile thinner. Generally give a full high-gloss film. Evaporation of nonvolatile content produces fast initial set that makes film dust-free in short time.

GRANODIZING—A cold-spray process of applying phosphate coatings to steel and other metallic surfaces to produce a crystalline and nonmetallic surface coating of zinc phosphate that tends to suppress destructive activity of galvanic action. Rust or corrosion does not spread beyond the area where accidental scratching or chipping has exposed bare metal. A typical process sequence involves precleaning the metal by spraying with an alkaline-emulsion cleaner, rinsing with clear water, coating with a phosphate known as Granodine, rinsing with clear water and rinsing finally with acidulated water. Bath temperatures are all under 120 F.

HARD-FACING—Application of a hard surfacing or facing to a metal by welding to prevent wear and provide resistance to heat and corrosion. Hard-facing materials are available as welding rods, as formed inserts, and in powdered form. The powders are spread over the base metal, and the base metal is heated to the melting point to firmly embed powder particles in the surface.

HYDROCARBON POLYMERS—Organic hydrocarbons not usually affected by water, acids, or alkalies. Except for polyethylene, not widely used as coating. Polystyrene may prove useful for coatings but the polymer is rather brittle, and plasticizers do not impart much flexibility. It cannot be blended with drying oils.

INHIBITOR—A substance added to the corrosive environment of a metal or alloy to decrease the corrosion rate. The two types are anodic inhibitors, such as soluble hydroxides, chromates, phosphates, silicates and carbonates that decrease corrosion of iron and other metals in aqueous media, and cathodic inhibitors such as magnesium, zinc or nickel salts that decrease corrosion of iron and steel under partial immersion. The action occurs at cathodic areas near the water line.

ISOMERIZED RUBBER—Natural rubber treated with acid chlorides or salts; varies from soft material to tough gum and hard material like shellac. Most combinations oxidize to hard glossy but flexible films. May be plasticized and blended with resins to provide other properties.

LACQUER—Very hard, glossy, nontacky film, airdrying or for baking. Clear or opaque colors. Vehicle is nitrocellulose or similar cellulose resin. Can be brushed or sprayed.

LEAD—Used mainly on iron and steel and usually applied either by burning on or rubbing with molten lead. Homogeneous lead coatings are ordinarily heavy and nonporous and are used for their resistance to chemical solutions. Sprayed coatings are also heavy but tend to be very porous relative to their thickness. Hot-dip lead coatings are seldom pure lead because of difficulties in obtaining complete coverage. Better results are had by first coating the iron or steel with zinc, tin or antimony. Both hot-dip and electrodeposited lead coatings are porous in commercial thicknesses.

LOHMANNIZING—Method of coating iron and steel sheets by immersing in a bath containing an amalgamating salt, then pickling and dipping in two different baths of molten alloys to provide a clean finished surface coated with a protecting metal. Alloys of lead, tin and zinc are used in various proportions in the process, to suit requirements. For roofing tin, the alloy coating on the sheet steel base contains 75% lead and 25% tin.

MELAMINE RESINS—Similar to the ureas in many properties. Can be modified by combination with butanol or capryl alcohol in the same way as the urea resins are modified. Employed primarily to impart hardness to alkyd resins.

MONTAN-CREOSOTE—A treating compound consisting of about 60% Montan wax and 40% creosote, used for preservation of wood outdoors as on poles and cross-ties. Treated wood is a good insulator. Pressure treatment provides essentially complete penetration of sap wood, with clean surfaces free from stickiness up to 140 F. surface cannot be painted.

NATURAL RESINS—Fossil gums and shellac, found in nature. Shellac, the most important, is widely used by itself

COATINGS . . . for insulation, surface hardening,

ACETAL RESINS—Widely used for surface coatings. Formaldehyde reacted with polyvinyl alcohol forms poylvinyl formal resin, used for wire coating. For greater hardness, a reactive phenol-aldehyde resin may also be incorporated with the acetal resin.

ACRYLATE RESINS—Polymers of the aliphatic esters of methacrylic and acrylic acid and their copolymers. Varying hardness; some are well adapted for coatings. Yield water-white films which do not discolor on exposure to heat or sunlight. Are resistent to water, acids, and alkalies. The films are thermoplastic and can be fluxed on baking.

ALKYD RESINS—Synthetic; can be modified to produce hard brittle resins, soft plasticizing resins, and polymers which resemble rubber and can be vulcanized. For additional hardness without loss of color, urea or melamine resins often added to alkyds. Drying-type alkyds are widely used with cellulose nitrate in lacquers.

ALUMINUM—Applied by a cementation process known commercially as calorizing, wherein the articles are packed in a container along with a mixture of aluminum oxide, powdered aluminum, and ammonium chloride, then heated in an inert atmosphere such as hydrogen while the drum is slowly rotated. Aluminum coatings are resistant to sulphur even at high temperatures and do not oxidize. Aluminum can also be applied by means of a molten spray and by the hot-dipping method; in the latter case heat-treating is required to improve the alloy bond.

ANODIZING—Formation of inorganic oxide coating on certain metals, chiefly aluminum, by connecting the metals as the anode in suitable electrolytes. Excellent protection on aluminum and widely used, but on magnesium and zinc less protective. With solutions of boric acid and borates, the oxide formed is substantially insoluble in the electrolyte, giving a thin, impervious coating as required in electrolytic capacitors and rectifiers. With solutions of sulfuric, oxalic and chromic acids, the oxide formed is slowly dissolved by the electrolyte, giving a porous coating, permeated by electrolyte, that grows as long as current passes. With fluoboric acid solution, the oxide dissolves as fast as it forms; properly done, this results in electrolytic polishing of the surface but no protection. The second type is generally employed for production of thick, porous protective coatings for corrosion protection of aluminum. There may be as many as one trillion (10^{12}) pores per sq in; these can be sealed by boiling water which transforms the aluminum oxide into aluminum monohydrate, by hot dilute solutions of nickel or cobalt acetate, or with oils, waxes or resins. For best service, anodic coatings should be kept clean by occasional washing or preferably by waxing; they can give good surface appearance for upwards of 10 years.

BITUMINS—Three types of bituminous coatings, for atmospheric use, immersion in water, and underground use. Primers are usually applied first, by dissolving the bituminous substance in a volatile solvent of the proper type to give a free-flowing, brushable and sprayable, quick-setting product. Upon drying, the primer serves as a thin adhesive coating to which the hot bituminous protective composition will firmly bond. The asphalts or pitches are often filled with ground slate, mica, talc, asbestos, or aluminum bronze powder to improve weather-resisting properties.

BONDERIZING—A process of producing on metal surfaces a phosphate coating that inhibits corrosion and increases adherence of paint. A typical application sequence that is carried out entirely with sheets moving on an overhead conveyer consists of an emulsion cleaner spray, two water rinses, spraying with Bonderite solution, a water rinse, and a final acid rinse containing a small amount of chromic and phosphoric acids, allowing about one minute in each of these sprays. After drying in an oven at 250 F for 1½ minutes, the sheets are sprayed with a zinc chromate primer in a paint spraying booth. The Bonderizing produces a grey crystalline phosphate coating on steel and a lighter, almost transparent grey film on aluminum. Widely used for metal cabinets, machine parts, fluorescent light fixtures and switch boxes.

BOWER-BARFF FINISH—Corrosion-resistant finish for steel, produced by heating the pieces in a closed retort to 1,600 F, then alternately injecting superheated steam and carbon monoxide to reduce the oxides formed on the surface to Fe_3O_4.

CADMIUM—Applied mainly to iron and steel, to copper and copper alloys, and to a smaller extent to aluminum alloys and zinc alloys. Electrodeposition from cyanide solutions is used almost exclusively. Deposition by immersion, metal spraying, and hot-dipping much less common. Copper wire has been hot-dipped in unalloyed cadmium. High chemical resistance to alkalies, to wet spray and immersion in sea water. Very slow formation of white corrosion products and tarnish films which interfere with moving parts and with surface conductivity for both ordinary and radio frequency currents; easy to solder with noncorrosive fluxes; no gouging and seizure of moving parts. If cadmium or cadmium plate is enclosed without air circulation with certain paints and certain impregnated fabrics or papers used for electrical insulation, very bulky white corrosion products may be formed through to the underlying base metal. High temperature and high humidity accelerate the attack.

CERAMIC COATINGS, HIGH-TEMPERATURE—Still relatively new. Crystalline porcelains developed at National Bureau of Standards have high dielectric and mechanical strength up to 2,000 F, using such materials as alumina, beryllia, zirconia, thoria and minor amounts of other metallic oxides but no silica. Typical composition is 84% beryllia and 8% zirconia; another is 80% zirconia, 10% beryllia and 10% magnesia. All have high thermal shock resistance and are good for electrical insulators, radar transformers and spark plugs.

CHLORINATED RUBBER—Hard, brittle, poor adhesion to metals and not resilient unless combined with plasticizers or modifying resins. Excellent chemical resistance. Good electrical characteristics below 120 C in air.

CHROMIUM—Applied by electroplating over a base coating of nickel or nickel-copper, or by cementation involving rotation of object in chromium powder during heating. Extremely hard, abrasion-resistant surface finish that will take and hold a high polish. Chromium coatings for corrosive industrial service require a thickness of not less than 75 microns. In electrodepositing thick chromium, the metal deposits over the cracks formed in the initial layer. While additional cracks continue to form, they and other conditions of deposition as well as the condition of the basis metal surface affect the porosity. Proper preparation of the original surface to eliminate pits and flaws is essential.

CHROMIZING—A process in which an alloy of chromium and iron is formed on the surface of steel parts by diffusion. The material to be treated is packed in a closed container with chromium powder and alumina and then heated to a temperature between 1,300 and 1,400 C in an atmosphere of hydrogen. The chromium content of the diffused layer is said to vary between 10 and 20%. The corrosion resistance of

SLUSHING COMPOUNDS—Nondrying organic coatings used for temporary corrosion protection as in intervals between stages of manufacture, assembly, shipment and use. Readily removed with available solvents. Usually consist of a petroleum derivative base containing additives that improve corrosion protection. Viscosity ranges from thin oil to semi-solids harder than heavy axle grease. May also serve as lubricants, as for protecting gears and bearings of radar antenna structures exposed to weather. Oil types of slushing compounds are not reliable rust-preventers except for short-term indoor use. Purpose of slush is to adsorb more strongly on metal surface than does water, forming layer through which water has difficulty in diffusing and which it cannot displace. Essential to clean parts thoroughly before application. In addition to applying by slushing or dipping, protection can be by spraying or fogging, brushing, flow coating, tumbling with inert material soaked in the compound, and swabbing with compound-soaked cloth.

SPRAYED METAL—Applied by feeding the desired protective metal in wire form through a special spray gun that melts and atomizes as it sprays. Roughening, generally by sandblasting, is required for adhesion of deposited metal to a surface. Useful for repairing coatings, for building up worn parts, and for applying copper coatings to carbon brushes and resistors.

TIN—Greatest use is in coating steel sheets to make tin plate in which the corrosion resistance, easy solderability, and sanitary appearance of the thin protective surface of tin is useful. Tin coatings applied also to wire for ease in soldering and for protection when a sulfur-bearing rubber insulation is applied to copper. Cast or fabricated iron and steel objects can also be tinned. Tinning by electrocleposition provides better thickness control and distribution than is possible by hot dipping. Coating thickness may be only 0.015 mil, the practical minimum for good solderability. As electrodeposited, the tin coating has a matte finish and no alloy layer. Heating the strip momentarily fuses the tin coating so that a bright reflective surface and a very slight alloy layer are formed. Electronic heating often used. A tin-alloy coating on most base metals can be readily obtained by deposition of tin from volatilized stannous chloride in a hydrogen atmosphere. Tin-sprayed coatings are frequently applied to equipment that cannot be readily tinned by other means, or for repair of equipment that cannot be economically dismantled for retinning. Tin loses its protective properties as soon as the iron or steel is exposed by scratches, because tin is electropositive to iron.

TIN-ZINC COATING—Protects steel from rusting. Most successful with 50 to 80% tin, balance zinc. Used on steel chassis units for radio sets and electronic equipment and on steel housings for electrical equipment. Can also serve as foundation for nickel-chromium plating not intended for high-temperature service.

UREA RESINS—Usually applied from alcohol solution thinned with aromatic hydrocarbons. When baked, a hard insoluble film is formed. The cured film is quite brittle. Alkyd resins are usually blended to impart some flexibility.

ULTRASONIC TINNING OF ALUMINUM—Method of removing oxide layer from aluminum and replacing it with a tin coating that alloys with the aluminum surface, by vibrating the aluminum sheet with ultrasonic waves as it is dipped into the molten tin bath.

VARNISH—A clear solution of drying oil and natural or synthetic resin. Drying takes place either by oxidation of the oils, evaporation of the solvent, or polymerization of the resin and oil. Classified as air drying or baking, depending on the method of drying. Used chiefly for protection of fabric, paper wood and other fibrous insulation against mechanical damage and moisture, and for improving insulating properties, increasing heat transfer, providing a surface finish and bonding layers of laminated materials. Six major types of insulating varnishes are: (1) Clear Baking Varnish, used for armatures, field coils, transformers and instruments; (2) Black Baking Varnish, similarly used when greater resistance to moisture, acids and alkalies is required along with higher dielectric strength; (3) Clear or Black Air Drying Varnish, for applications where baking is not feasible; (4) Clear or Black Finishing Varnish, used over baking varnishes to improve appearance, give a harder surface, and protect against oil, moisture, dirt and metal dust; (5) Sticking Varnish, for cementing cloth, paper, mica, etc; (6) Core Plate Varnish, for insulating laminations of transformers and armatures. Oil varnishes are usually applied by hot dipping or vacuum impregnation, while finishing varnishes are applied by brush or spray.

VINYL-TYPE COATING (Acraclad)—Newly developed line of synthetic finishes that can be applied to all ferrous and nonferrous metals without pretreatments or primer coats. Dries in 2 to 20 minutes at 250 to 350 F. Solid content can be up to 40%, providing stabilized coating with good hiding power. Odorless, tasteless, nontoxic; available in all standard colors as well as water-clear and transparent shades, varying from flat and satin finishes to high glosses. Average coverage is 400 sq ft per gallon. Successfully used also on molded phenolic plastics such as radio cabinets. Can be applied by all conventional methods, including brushing, dipping, spraying, flushing or flow coating, and roller coating. Drying is by evaporation of volatile solvents, but heat from convection or infrared ovens required to complete the curing cycle and fuse the coating to the metal or plastic surface. Surface must be carefully cleaned and degreased to get good adhesion.

VITREOUS ENAMELS—Made by melting together such materials as feldspar, borax, quartz, soda ash, fluorides, color oxides, and opacifiers to form a moulten glass. This is poured into a stream of water which shatters it to broken glass or frit. The frit is ball-milled either wet or dry and applied to the prepared metal shape by dipping, spraying, or dusting. Heating in a furnace at about 850 C melts the coating into a continuous layer of glass.

ZINC—Commonest protective coating for protection of steel and structural iron. Protects by electrochemical action when steel is exposed at cut edges. Earliest method, the hot-dip process, is still very widely used; for galvanizing wire modifications known as the Crapo process and the Herman or Galvannealed process are used. Also electroplated and spraved or in molten form. In the tropics, corrosion of zinc coatings is rapid, resulting in white coating of basic zinc carbonate. Inhibitive chromate films retard this action. The newer cementation or sherardizing process involves heating and slowly rotating the articles for several hours in a container packed with zinc dust.

ZINC-BASE FINISH—Object is first zinc-plated conventionally, then placed in chromate-type bath to produce electrolytic formation of a zinc conversion coating. Resulting finish is highly corrosion-resistant and has a bright metallic appearance somewhat like chromium plating.

ZINC CHLORIDE—Standard water-soluble wood preservative; odorless, clean, low in cost, and fire-retardent. Surface can be painted after treatment, but preservative action does not last as long as with creosote.

ZINC META-ARSENITE—Odorless, colorless powder used as wood preservative. Applied at ordinary temperatures by pressure treatment. Treated wood is nonconductor of electricity, highly toxic to insects, noncorrosive to iron and steel, and can be painted or varnished. Does not affect tensile strength of wood. Very low solubility in water.

as an insulating and protective finish, and is marketed as flakes, buttons and cakes; it is a purified resin made from lac, which consists of excretions from certain insects.

NATURAL RUBBER—Used as sheets cemented to metal to provide resistance to abrasion, acids, alkalies, salt spray, water, and many other chemicals, and serve as electrical insulation. Drawbacks are poor oil resistance, brittleness at low temperatures, and lack of resistance to aromatic and chlorinated hydrocarbons. Rubber latex itself can be compounded with water dispersions of carbon black, fillers, and accelerators to give coating compositions that can be applied as films and vulcanized in place with heat.

NICKEL—Used for protection from corrosion and to present a bright and pleasing appearance in all kinds of atmospheres, outdoors and indoors. Nickel coatings on brass articles prevent seasonal cracking. Decorative coatings are applied by electrodeposition. Usually parts are plated after fabrication, but the use of preplated strip is increasing sharply because of lower finishing costs and greater uniformity of coating. Quality, cleanliness, and smoothness of the metal surface influence porosity but become less important as thickness of deposit is increased. Zinc or cadmium coating under nickel may cause white stains and blistering without increasing the protective value. Coating thickness of 30 microns of nickel on steel is about equivalent to one of 25 microns on zinc alloys or 10 microns on brass. Sprayed coatings of nickel can be applied but for corrosive applications they must be made relatively thick, with minimum thickness of 0.8 mm. Extremely thin coatings of nickel alloyed with the base metal or with superimposed layers of other metals by diffusion have been produced. Nickel-zinc diffused coatings show amazing resistance to the standard salt spray.

NICKEL-CLAD STEEL—Steel with a pore-free layer of wrought nickel which is bonded metallurgically and cannot separate as a result of thermal or mechanical treatment. It is available in large and thick plates. Used where the chemical and mechanical properties of nickel are required at a lower cost than that of solid wrought nickel. Standard claddings of 5, 10, 15, and 20%, on one or both sides, are available.

OXIDES—Black coatings are obtained on steel by treatment in strong alkali solutions containing an oxidizing agent at temperatures of about 140 to 150 C. For producing the coating on steel, caustic soda is usually employed in conjunction with such oxidizing agents as sodium nitrite, nitrate, or chlorate. Other methods, such as quenching in oil, are employed for producing oxide coatings on ferrous articles. Little dimensional change in articles results from the oxide coating, and it can be used on precision parts requiring close tolerances. A black finish is produced on copper and brass by direct oxidation at low temperatures. The coating after oiling exhibits good corrosion resistance by salt-spray test and can be used for increasing the adhesion of applied paint films.

PAINT—Originally a mixture of pigments usually in organic oxides, with a drying oil such as linseed oil; now considered as any combination of pigment and vehicle that can be brushed and air-dries to a tough adherent coating.

PARCO LUBRIZING—A chemical treatment for producing a phosphate coating on iron and steel surfaces to prevent wear. The thoroughly cleaned articles are dunked for about 15 minutes in a solution of Parco Lubrite held at near boiling. The coating thereby produced absorbs and retains oil on bearing surfaces, permitting rapid break-in of wearing parts and retarding subsequent wear and corrosion. Finish is matte black; does not impair elasticity of fine springs nor alter magnetic properties of iron and steel.

PARKERIZING—Corrosion-resistant chemical coating produced by immersing iron or steel in a solution of manganese dihydrogen phosphate, then heating to about boiling point until effervescence ceases. Product is then oiled, producing surface finish having appearance of gun metal. Phosphate coatings such as this are used chiefly as bases for enamels and paints, however.

PASSIVATOR—An inhibitor that, when added to the environment of an iron or alloy, appreciably changes the electrochemical potential to a more cathodic value. An example is chromate, which makes iron stay bright indefinitely in water if added to the water insufficient quantity. It thus serves in lieu of a protective finish.

PEELABLE PLASTIC—A film-forming resinous compound carried in a volatile vehicle, applied to surfaces as a rust preventative and for surface protection during forming operations. The film adheres tightly to metals but can be stripped from coated surfaces easily. Used as a protective coating and as a lubricant in drawing operations on stainless steel. Can be used as a packaging material or cocoon when sprayed onto a framework of tape connecting the outermost projections of the part.

PETROLEUM DRYING OILS—Hydrocarbon resins from cracked gases or from the polymerization of dienes. Color very dark, they polymerize further on baking to insoluble but brittle films.

PHENOLIC RESINS—Adapted to diverse types of application. Some are used as fortifying resins with drying oils, others are designed for use directly. Soluble in alcohols and aromatic solvents and require baking at about 180 C for 10 to 40 minutes. The cured film resists water, acids, alkalies. Baked films are usually dark, and become increasingly brittle as cure is completed so thin films must be employed.

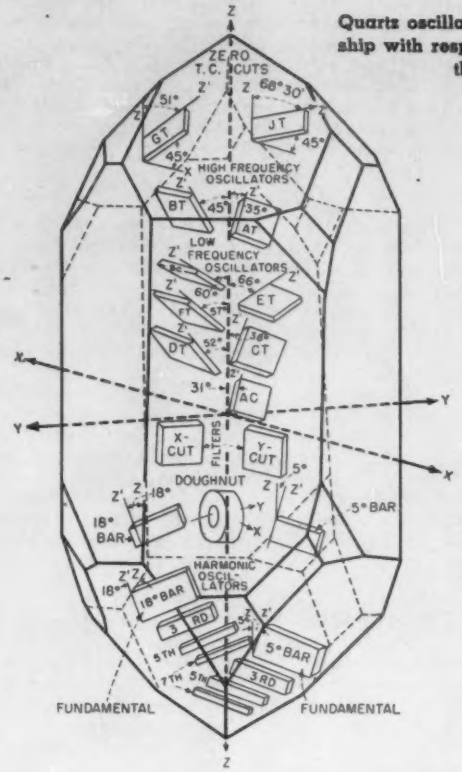
PHOSPHATES—Coatings on metals resulting from chemical reaction of phosphoric acid and metal surface to form nonmetallic coating. Coating solutions react chemically with metal so that surface is converted into crystalline phosphate coating. Paint finishes over phosphate-coated surfaces are said to increase durable life of finish. Phosphate coating retards under-film corrosion and spread of corrosion if paint film is scratched. Nuts, bolts, screws and such parts are often phosphate coated and finished with oil for corrosion prevention.

PLATING ON PLASTICS—Initial copper film is put on a plastic object by reduction of copper from a Fehlings solution with a metallo-organic derivative of sodium hydrosulfite. Intermediate layer of copper or silver is applied conventionally by electroplating, followed by final layer of metal.

PROTECTATIN—A process of applying a thin, invisible oxide film on tinplate to protect against staining and rusting, as well as to provide a good base for paint on very thin electrotinned plate. The tinplate is simply dipped for about 20 seconds in a hot alkaline phosphate dichromate solution containing a suitable wetting or penetrating agent.

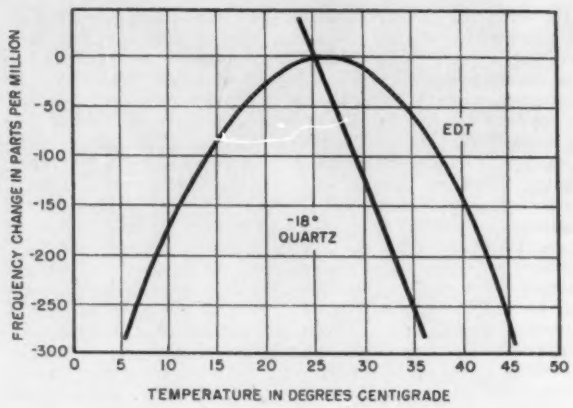
SHERARDIZING—A method of applying a thin zinc coating to metal parts, involving tumbling the parts in a mixture of zinc dust at a temperature of about 800 F. The zinc dust does not melt, but rather adheres by a form of amalgamation process. Preliminary cleaning is highly essential, either by sand blasting or by pickling in acid and then neutralizing in boiling cyanide solution.

CRYSTALS . . . *·quartz, synthetic piezoelec-*



Quartz oscillator and filter cuts showing their angular relationship with respect to the X (electrical), the Y (mechanical), and the Z (optical) axes of a mother crystal

Comparison of temperature coefficients for ethylene diamine tartrate and quartz crystals. The graph shows the characteristic for one of the useful cuts at EDT. Other quartz cuts are superior in temperature coefficient but can not be compared for low-frequency use [A]



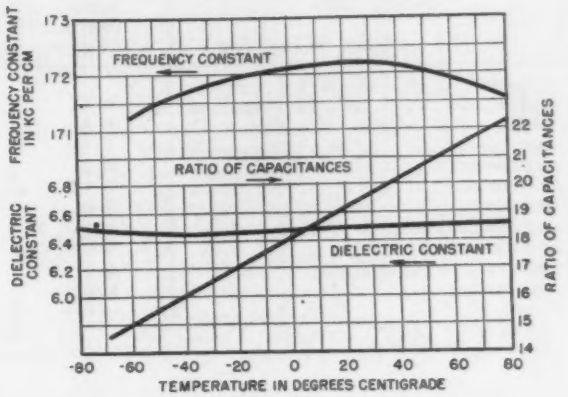
Constants of Some

Cut	Length (l)	Breadth (b)	Thickness (e)	Fundamental frequency	*R*
	mm	*mm*	*mm*	*kc/sec*	*ohms*
X-bar	62.2[E]	7.5	1.5	44	1,640
X-bar	30.7[E]	4.1	1.4	89.9	15,000
X-bar 79.5 deg	24.03	2.5	0.502	130.7	———
X-bar 18.5 deg	20.0	2.5	0.502	127.7	———
X-bar 0.9 deg	19.97	2.99	0.502	135.2	———
X-bar−18 deg	20.02	2.95	0.50	155.4	———
X-bar−42.6 deg	20.0	2.95	0.50	174.8	———
X-plate	16.40[E]	15.64[F]	6.15	472	2,100
X-plate	Disk, diam 48.5 *mm*		7.52	389	400
X-plate	Disk, diam 9.43 *mm*		0.58	4,980	4.6
X-plate	Disk, diam 25.0 *mm*		1.89	1,500	12.7
Y-plate	Disk, diam 25.0 *mm*		1.28	1,500	8.4
BT	Disk, diam 25.0 *mm*		1.66	1,500	35.0
AT	Disk, diam 25.0 *mm*		1.10	1,500	24.2

(A) From a paper by J. P. Griffin and E. S. Pennell, Bell Telephone Labs., presented at an AIEE meeting.
(B) Abridged from W. G. Cady, "Piezoelectricity," McGraw-Hill Book Co., New York, 1946.
(C) Wave constant *H* equals *fl* for bars and *fe* for plates when *f* is in kilocycles and *l* and *e* in millimeters.

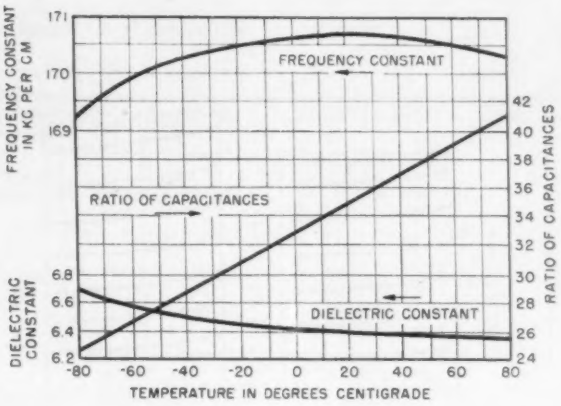
tric, silicon, selenium and copper-oxide characteristics

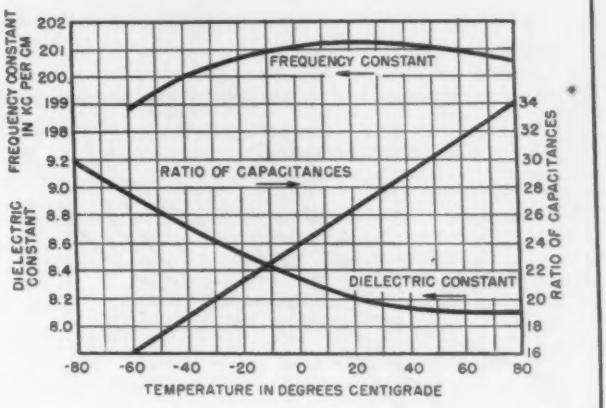
Frequency constant, ratio of capacitances, and dielectric constant for a 45-degree Z-cut di-potassium tartrate (DKT) crystal. It has a higher coupling than the Y-cut EDT and a frequency variation only a third that for the EDT. The type will doubtless prove extremely useful when processing methods are perfected [G]



Some characteristics of Y-cut EDT crystals suitable for wide-band filters where high electromechanical coupling and moderate temperature stability are required. More complicated orientations are necessary to obtain improved characteristics desired between those of the A and Y cuts (lower right) [G]

Frequency constant, ratio of capacitances, and dielectric constant for an A-cut EDT crystal from which all elements of the equivalent circuit of a crystal can be calculated. Because of its relatively flat temperature-frequency characteristic this cut is useful in narrow-band filters where low coupling and high stability are required [G]





Typical Quartz Resonators[H]

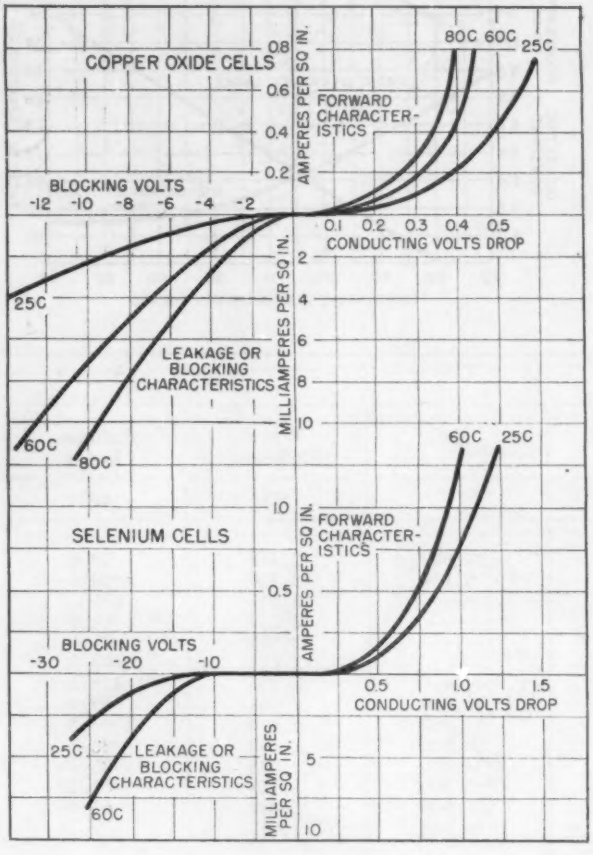
L	C	C_1	$\frac{C_1}{C}$	Q	Wave Constant	Stiffness factor
henrys	$\mu\mu f$	$\mu\mu f$			H^C	$q_0{}^D$
216	0.06	8.7	145	37,000	2,740	79.6
137	0.0205	3.54	173	5,150	2,750	80.6
———	———	———	———	———	3,141	105
———	———	———	137	———	2,554	69.2
———	———	———	———	———	2,705	77.5
———	———	———	———	———	3,111	102.5
———	———	———	———	———	3,495	129.5
28.2	0.004	1.93	460	40,000	2,900	89.0
9.25	0.018	9.6	530	57,000	2,920	90.8
0.00725	0.14	26.3	190	50,000	2,890	88.5
0.181	0.0622	10.2	164	134,000	2,838	85.46
0.056	0.2011	15.0	75	63,000	1,919	39.10
0.391	0.0288	11.9	413	105,000	2,492	65.99
0.119	0.0945	17.9	189	46,500	1,657	29.23

(D) Stiffness factor q0 in dynes per sq cm X 10^{-10}
(E) Cut parallel to Y axis
(F) Cut parallel to Z axis
(G) From a paper by W. P. Mason, Bell Telephone Labs., published in the *Proc. I. R. E.*

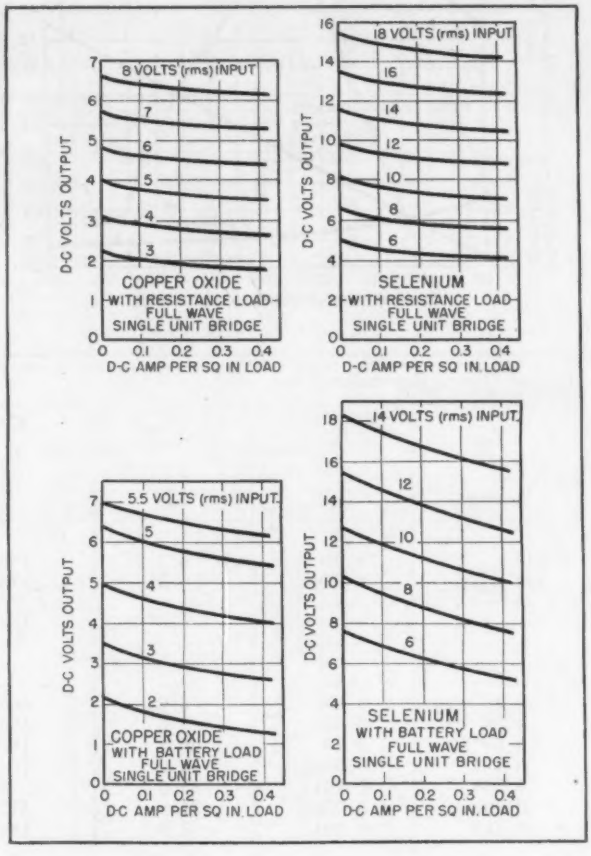
Rectification Characteristics of Some Samples of High-Inverse-Voltage Silicon Rectifiers[H]

Doping agent	Amount added, *percent*	Beryllium added, *percent*	Typical performance		
			Peak back voltages, *volts*	Back resistance at 15 v, *ohms*	Forward current at 1 v, *ma*
Nickel	0.16	0.02	45	30×10^3	2
Nickel	0.6	0.02	40	10	5
Tin	0.4	0.02	60	10	0.05
Germanium	0.5	0.02	60	10	0.25
Germanium	0.75	0.02	40	5	1
Germanium	1.0	0.02	30	2	2
Germanium and nickel	0.3, 0.06	0.02	70	100	0.2
Bismuth	0.02	0.02	40	3	1
Calcium hydroxide	0.1	0.01	80	50	0.1
Aluminum	0.006	0.02	5	—	10
None	—	0.02	90	30	0.1

(H) H. C. Torrey and C. A. Whitmer, "Crystal Rectifiers," McGraw-Hill Book Co., 1948.
(I) From an article on copper-oxide and selenium rectifiers by W. H. Falls, published by G. E. Review, Feb. 1947.



Forward and leakage volt-ampere characteristics of copper-oxide and selenium cells at several temperatures within and slightly beyond the operating range [I]



Regulation characteristics of copper-oxide and selenium rectifiers with either battery or resistance load. The type of rectifier chosen will depend upon use [I]

FLUORESCENT COMPOUNDS . . .

colors, luminous efficiencies and special characteristics that determine applications of inorganic compounds used in screens of cathode-ray tubes

Compound	Activator	Chemical Symbol	Fluorescent Color	Luminous Eff. in Candles per Watt below 1 KV	Luminous Eff. in Candles per Watt below 6 KV	Applications and Remarks
Zinc sulfide	none	ZnS	pale blue	...	...	Unactivated, ZnS is relatively inefficient; it is the basic material from which most screens are made (Note A)
Zinc sulfide	copper	ZnS:Cu	yellow-green	2	12	Oscilloscopes for daylight viewing and photography, long persistence holds transients; RMA-P2
Zinc sulfide	silver	ZnS:Ag	actinic blue	2	0.4	Short persistence (0.005 sec), alternate to zinc orthosilicate for general oscilloscopic use, most suitable of all common screen materials for photographic recording (Note B)
Zinc sulfide	manganese	ZnS:Mn	orange	1.5	1.5	For low-voltage tubes
Zinc cadmium sulfide	copper	ZnCdS:Cu	orange-yellow	1.5	6	Medium to long persistence, phosphorescent, component of RMA-P7 radar screen (Note B)
Zinc cadmium sulfide	silver	ZnCdS:Ag	yellow	2.5	10	Short persistence, daylight viewing and photography, component of RMA-P6 (Note B and Note C)
Cadmium sulfide	copper	CdS:Cu	deep red	...	...	Not very active (Note C)
Zinc silicate	manganese	$(2ZnO\text{-}SiO_2\text{-}H_2O)$:Mn	green	3.5	9	Medium persistence for general oscilloscopic work; zinc silicate is commonly called calamine, zinc orthosilicate is commonly called willemite (Note D)
Zinc orthosilicate	manganese	$(2ZnO\text{-}SiO_2)$:Mn	green			
Zinc beryllium silicate	manganese	$ZnBeSiO_4$:Mn	yellow-green	1.2	5	Alternate to Zn_2SiO_4 for general use, medium persistence (0.05 sec), RMA-P3 used in early television tubes
Cadmium tungstate	none	$CdWO_4$	.....	0.3	0.8	The tungstates, although of little importance in cathode-ray tubes, are among the few materials that fluoresce without an activator; manganese activates $CdWO_4$; it is very sensitive to ultraviolet rays
Calcium tungstate	manganese	$CaWO_4$:Mn	blue	0.3	1	Stable photographic screen, without an activator $CaWO_4$ is RMA-P5 used for observing and photographing transients, blue-violet, very short persistence (5 microsec); also used in intensifying screens for x-ray examination
Cadmium borate	manganese	.....	red	1	3	Night viewing navigation indicators short persistence, not sensitive to ultraviolet rays and so used in airplane cockpits
Calcium phosphate	dysprosium	.....	white	0.4	1.5	Long persistence, not sensitive to ultraviolet rays and so used in cockpits where other instruments are illuminated by ultraviolet light light shining on their fluorescent dials
Zinc phosphate	manganese	.....	red	...	...	Sometimes used as special purpose persistent screen in tubes for cardiographs

Color and activity of fluorescence of cathode-ray tube screen materials depend on composition, crystallization, and method of preparation. This table presents the usual properties of commonly employed materials as they are generally prepared for this purpose. Values are representative of current commercial practice but not necessarily standard; they vary with operating conditions and within manufacturing tolerances. Not only are these materials sensitive to cathode rays, they also fluoresce under other irradiation. In general the efficiency of conversion to visible light is from 1 to 5 percent under x-rays, 5 to 10 under cathode rays, below 70 under ultraviolet, and about 80 under alpha particles. Sensitivity to ultraviolet varies considerably; those materials that are relatively insensitive to ultraviolet are used in tubes grouped with other instruments.

Note A—Sulfides are the most important of materials used for cathode-ray tube screens. Activity depends chiefly on impurities in the base materials. Addition of as little as 0.00001 percent silver turns the color from ZnS to deep blue; or addition of 0.001 percent copper turns it green and adds persistence; nickel in small quantities acts to quench the response. Using ZnS and CdS in various percentages and activated with Cu or Ag, fluorescenses from red to blue can be obtained; mixtures high in ZnS are in the red, those high in CdS in the blue; the ZnS is by far the more efficient.

Note B—ZnS:Ag is twice as effective for photographic recording as television white, which is the next best material in that respect. ZnS:Ag is equally useful with all film emulsions and over a wide range of writing speeds. It is a component of RMA-P6 screen, which is used as an alternate to RMA-P4. RMA-P6, white, medium persistence (0.005 sec) is composed of ZnS:Ag and ZnCdS:Ag. ZnS:Ag is also a component of RMA-P7 giving it a medium persistence in the blue, the other constituent, ZnCdS:Cu, gives it long persistence in the yellow; together these two components tend to integrate or average out noise in the intensity modulation. ZnS:Ag plus Ni as a quencher, ZnS:Ag:Ni, is RMA-P11 blue, very short persistence (10 microsec) used for photography and as an alternate to RMA-P5, $CaWO_4$; RMA-P11 has the higher efficiency. ZnS:Ag is also used as an exciter for long-persistent screens (as in RMA-P7).

Note C—Also ZnS:Ag & CdS:Ag, bright yellow, used for radar in daylight without a filter, with a tricolor red filter at night; mixture and compound not clearly distinguished in literature. Zinc-cadmium sulfides activated with Cu and Ag are used as a double-layer screen having a blue and a yellow emission when excited by cathode rays; it is known as AB screen in England, and used for moderately long persistence displays in navigational equipment, compare RMA-P7 (Note B). ZnCdS:Cu has an orange afterglow; it is used for night viewing, but not in cockpits.

Note D—Zinc silicate and orthosilicate are not clearly distinguished in the literature, both apparently being called willemite. Zinc orthosilicate activated with manganese is used for daylight viewing, and being insensitive to ultraviolet light, is used in cockpits as are also most silicates and phosphates; it has high efficiency at low voltage and so is used in low-voltage tubes, as is the cubic form of ZnCdS. Silicates are less apt to burn under electron bombardment than sulfides. Zinc orthosilicate (RMA-P1) green is most commonly used for oscilloscopes because it combines high light output, stability, and ease of maintaining uniform quality in manufacture. Without an activator it fluoresces blue, or red if heat quenched in processing. Persistence can be increased by adding about 0.4 percent arsenic oxide with 3 percent Mn activator. Lithium chloride quenches its response. Be as an activator produces yellow to green depending on ratio of Be to Mn and firing temperature; high Mn, Be, and temperature shift fluorescence into orange.

INSULATING COMPOUNDS . . .

	Dielectric Constant at 1 mc	Loss Tangent[c] at 1 mc	at 10 mc	at 100 mc	Density at 25 C	Temperature, Soft, C or Pour Point	Appearance	Composition
Cable Oil 5314	2.3	0.001	0.002	0.006	0.89[4]	−40 P.P.	Very pale amber, clear	———
D-C Fluid 200, 300	2.5	0.0001	0.0001	0.0001	0.9559	——	Water white	
Fractol A	2.2	0.0001	0.0002	0.0004	0.8	<−15P.P.	Colorless, clear transparent	Mixed petroleum hydrocarbons
Halowax Oil 1000	4.8	0.0002	0.00025	0.011	1.19	——	Water white	Chlorinated napthalene, 25% chlorine
Pyranol 1476	4.0	0.21	0.06	0.015	1.5[4]	10 P.P.	Clear, straw yellow	Pentachlorodiphenyl and trichlorobenzene
Transil Oil 10C	2.25	0.0002	0.0003	0.0012	0.88[4]	−40 P.P.	Very pale amber, clear	———
Shellac								
Dewaxed Garnet	3.4	0.028	0.032	0.032	1.2	75	Dark garnet flakes	Natural shellac, wax free
Garnet, CP	3.5	0.03	0.034	0.034	1.2	82	Same, thick flakes	Natural shellac, 2% natural wax
XL (natural)	3.5	0.031	0.035	0.031	1.2	80	Light orange flakes	Natural shellac, 3.5% natural wax
Zinfo, 3164	3.5	———	———	———	1.2	80	Dark orange in thin flakes	Natural shellac, 3.5% natural wax
Ethyl Polychlorobenzene	4.1	0.00095	0.006	0.06	1.52[4]	——	Colorless	Ethyl tetrachlorobenzene and ethyl pentachlorobenzene
Primol D	2.16	0.00025	0.00026	0.00032	0.89[4]	<15 P.P.	Colorless, clear	Mixed petroleum hydrocarbons
Bayol 16	2.15	0.00012	0.0002	0.0004	0.85[4]	0 P.P.	Colorless, clear	Mixed petroleum hydrocarbons
Mycalex K 10	10.6	0.0038	0.003	———	2.97[4]	400	Cream, opaque	Mica, glass, titanium dioxide
Gilsonite	2.6	0.0015	0.0012	0.0011	1.04	Melting point 155 C	Black, brittle	Asphalt
Ignition Sealing Compound 4	2.8	0.0003	0.0005	0.0023	0.99	——	Colorless grease	———
Micalex 1364	7.0	0.0021	0.002	0.0022	2.95	——	Gray, smooth surface	Ground mica and soft glass
African Mahogany						Modulus Elasticity		
90% humidity	3.0	0.04	0.038	0.043	0.668 (air	1.55×10^6	———	———
0% humidity	1.7	0.024	0.039	0.04	dried)	——	———	———
Balsa Wood	1.4	0.012	0.0138	0.0138	0.16 (air dried)	——	———	———
Water, Distilled	79.	0.023	0.0021	0.0048	——	——	———	———
Ice, −12C	4.1	0.1	0.01	0.0039	——	——	———	———
Sea Water (Lab. syn.)	78.	200	30	4.0	——	——	———	2.285% sodium chloride
Sulfur	3.4	0.0002	0.0002	0.0001	——	——	———	———

dielectric and physical properties of some liquid and solid materials

Moisture Absorption at 27C percent	Flammability or Fire Point C	Chemical Resistance to: Acids	Alkalies	Water	Oxygen	Electrical Strength	Toxicity	Flash Point, C	Remarks
———	185	———	———	———	———	———	———	155	Filler for dielectric cables
<0.1	Flam. low	Dilute, good	Fair	Excellent	Excellent	———	Keep from eyes	330	Waterproof ceramic and glass, dielectric material
Slight	210	Excellent	Excellent	Excellent	Excellent	300	Tox. Nil	182	High-frequency high-temperature liquid insulator
———	170	———	———	———	———	———	Avoid continuous contact	———	Petroleum additive, index of refraction standard
———	Flam. <200 F. P. 210	———	———	———	———	———	Slight	———	Capacitor, transformer oil
———	———	———	———	———	———	———	———	135	Transformer oil
Low after baking	Very slow	Dilute, good	Poor, unless baked	Good after baking	Good	———	———	———	Special uses
Low after baking	Very slow	Dilute, good	Poor, unless baked	Good after baking	Good	———	———	———	Used where dark color not objectionable
1.5%, 50% humidity 1.8%, 100% hum. Low after baking	Very slow	Dilute, good	Poor, unless baked	Good after baking	Good	———	———	———	High grade for electrical use. Good color
1.5%, 50% humidity 4.8%, 100% humidity. Low after baking	Very slow	Dilute, good	Poor, unless baked	Good after baking	Good	———	———	———	Used where dark color not objectionable
———	No F. P. to 270C	Good	Good	See Note[B]	Good	———	Avoid contact and vapors	———	Transformer and capacitor dielectric, heat-transfer fluid
Slight	F >200	Excellent	Excellent	Excellent	Excellent	300	Nil	<−15	High-frequency, high-temperature liquid insulator
Slight	F >200	Excellent	Excellent	Excellent	Excellent	300	Nil	———	High-frequency, high-temperature liquid insulator
<0.5	———	Poor	———	Good	———	———	———	———	Capacitor dielectric
———	———	———	———	———	———	———	———	———	Softener, diluent for rubber
———	Burns	———	———	Excellent	———	500–0.01 in. gap	———	———	Moisture seal ignition cable junctions, radio, radar connectors
0.003	———	———	———	———	———	360–0.2 in. thick	———	———	High-temperature insulator

[A] Approximately 15C.
[B] Six hours boiling with water yields 0.005% chlorides.
[C] Loss Tangent = Loss Factor/Dielectric Constant.

Abridged from Tables of Dielectric Materials, Reports V and VIII, Laboratory for Insulation Research, MIT, NDRC Contract OEMsr-191.

for laminated, solid and powdered metal cores and for permanent magnets

Coercive Force H_c oersteds	Electrical Resistivity μohm cm	Core Loss 29 gage 60~ B=10,000 watts/lb	Density lb/cu in.	
0.495–0.64	18–19	1.30	0.278	
0.45–0.62	25–28	1.17	0.28	
0.375–0.55	35–45	1.01	0.28	
0.35–0.51	41–56	0.82	0.275	
0.33–0.42	46–60	0.72	0.27	1
0.31	——	0.65	0.27	
0.16–0.24	58	0.58	0.27	
0.16–0.2	60	0.52	0.27	
0.1	45–48	0.34–0.48	0.268	2
4.6	30	——	——	
1.0	11	——	0.285	
0.65–0.95	22–60	——	——	
0.6–1.0	10	——	0.285	3
0.05	10	——	0.285	
10	9	——	0.32	
3.4	8	——	0.32	
1	80	——	——	4
0.3	45–50	——	0.295	5
0.3	55	——	0.3	
0.03–0.1	35–52	——	0.3	6
0.014–0.02	55–56	——	0.317	7
0.015–0.05	25–60	——	0.31	
0.05–0.06	16–17	——	0.31	
0.05	65	——	0.31	
0.05	55–57	——	0.315	8
0.004	60	——	0.32	
0.05–0.07	58	——	0.316	
2	7	——	0.3	9
2	26	——	0.296	
1.2–1.4	19	——	0.311	
0.62	80	——	——	10
0.6	16	——	0.311	
4–5	——	——	——	11
——	10–45	——	0.2	
——	16–40	——	——	12
0.05	80	——	——	

1. Commonly called electrical steels. Values are for 29 gage sheets (0.014 inch thick). For coiled strip, values of Armature and Electrical grades are appreciably higher than those given here. Armature and Electrical grades are slightly aging. In general, increasing silicon content makes sheets harder and stiffer while improving magnetic properties and reducing core loss. First four grades are used chiefly for core laminations of motors, generators, reactors, power transformers, and other power-frequency applications. Transformer grades are used for audio transformers as well as small power transformers and higher-quality motors. Special thin transformer sheet steels, down to 0.001 inch thick, are available for higher-frequency applications up to 2 mc and higher.

2. Values are for 29 gage, measured in direction of rolling. With flux transverse to rolling direction, core loss goes up to about 0.6. Used for rolled steel cores, with butt joints so flux always travels in rolling direction. Typical trade names are Hipersil and Corosil.

3. Available in bars, rods, wire, and in some cases sheets. Used chiefly for relay cores, principally in d-c applications.

4. Thermomagnetic (permeability decreases as temperature increases) in usable temperature range to serve as temperature-compensating magnetic shunt for permanent magnets, airplane tachometers, and watthour meters. With 32.5 Ni content its chief use is as temperature compensation for electromagnets like those in voltage regulators and contactors.

5. Alloys with nickel content ranging from 35 to 90 Ni are generally called permalloys, and are marketed under a wide variety of trade names. Characteristics are determined largely by nickel content. Used chiefly for transformer laminations. 45 Permalloy has highest magnetostriction effect among these alloys, but must be laminated to limit eddy current loss.

6. Alloys with approximately equal content of nickel and iron are available under a variety of trade names, such as Hipernik, Isoperm, Nicaloi, 49 Alloy, etc. Characteristics differ according to nickel content and nature of initial processing and annealing. Isoperm, for instance, is available in 1.7 mil sheets having initial permeability of 85, with equally low hysteresis loss, developed in direction of rolling after excessively hard rolling, annealing, and final moderately hard rolling. Used for high-frequency transformer cores and where compact light-weight cores are needed.

7. Permalloys with appreciable copper content, for transformers. At 65–70 Ni the magnetic anneal effect is most pronounced; the material is magnetized several oersteds during anneal at 400 to 600C, increasing the maximum permeability and reducing the coercive force.

8. Permalloys characterized by high initial permeability, low hysteresis loss and minimum magnetostriction effect. Widely used for cores of transformers, sensitive relays, etc.

9. Iron-cobalt alloys having high saturation flux density, coupled with high tractive force at these densities. Used for electromagnets and telephone receiver diaphragms. Addition of Vanadium permits rolling to sheets a few thousandths of an inch thick.

10. Iron-cobalt-nickel alloys having remarkably constant permeability in low magnetic fields. Used for continuous loading of submarine cables. Note low Curie temperature.

11. No ferromagnetic element. With tin instead of aluminum, saturation values over 8,000 have been attained.

12. Powdered materials, available in wide range of particle sizes and compressed or cast to desired core shape for loading coils and high-frequency coils. Density varies with molding pressure, which generally ranges from 50 to 100 tons per sq in. Permeability value is controlled largely by binder used for particle insulation. Types of iron powders available include pure iron, electrolytic iron, carbonyl iron, hydrogen-reduced iron, Ferrocart, magnetite, etc.

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MAGNETIC MATERIALS . . .

Magnetic Material	Chemical Composition	Initial Permeability	Maximum Permeability	Saturation *gauss*	Hysteresis Loss at Sat. *erg/cm³/cycle*	Residual Flux Density B_R (from 10,000) *gauss*
ELECTRICAL STEELS:						
Armature	0.5 Si, 99.5 Fe	—	5,500–5,800	21,000	4,500	8,350–12,800
Electrical	1 Si, 99 Fe	—	5,700–6,100	21,000	—	7,700–7,900
Motor	2.5 Si, 97.5 Fe	—	5,500–6,100	20,000	—	6,350–7,300
Dynamo	3.25 Si, 96.75 Fe	—	5,800–6,000	20,000	—	6,650–7,000
Transformer 72	4 Si, 96 Fe	400	6,300–6,700	20,000	3,500	6,200
Transformer 65		—	7,000	19,500	—	5,200
Transformer 58		—	8,000–8,300	19,500	—	5,050–5,900
Transformer 52		—	9,000	19,500	—	4,800–5,700
Oriented-Grain Steel	3–3.3 Si, bal. Fe	—	17,500–40,000	20,000	—	—
SOLID CORE METALS:						
Cast Iron	2 Si, 3 C, 95 Fe	—	600	—	20,000	5,300
Ingot Iron	99.8 Fe	—	7,000	22,000	—	13,000
Silicon Core Iron	1–4Si, 0.15Mn, 0.08C, bal. Fe	—	2,000	20,500	2,500	1,800–2,750
Magnetic Iron	99.9–99.94 Fe	200–250	5,000–5,500	21,500	5,000	13,000
Hydrogen-Reduced Iron	99.98 Fe	25,000	275,000	21,500	300	13,600
Cobalt	99 Co	70	240	18,000	2,000	5,000
Nickel	99 Ni, 0.2 Cu, 0.4 Fe	110	600	6,100	3,000	3,600
MAGNETIC ALLOYS:						
Temperature Compensator	29.5–32.5 Ni, bal. Fe	—	—	4,200	—	3,000–3,500
45 Permalloy	45 Ni, 0.6 Mn, 54.4 Fe	2,500–2,700	23,000–25,000	16,500	1,200	8,000
Radiometal	47 Ni, 3 Cu, 49 Fe	2,500	25,000	15,600	—	—
50–50 Nickel–Iron Alloy	45–50 Ni, bal. Fe	3,000–9,000	40,000–150,000	16,000	—	6,000–8,000
1040 Alloy	71Ni, 15Cu, 1Mn, 3Mo, 10 Fe	40,000	100,000	6,000	200	2,500
Mu Metal	74 Ni, 5 Cu, 1 Mn, 20 Fe	7,000–25,000	80,000–110,000	8,500	—	2,300–6,000
78.5 Permalloy	78.5 Ni, 0.6 Mn, 20.9 Fe	9,000–15,000	100,000–105,000	10,700	200	6,000–9,000
3.8–78.5 Permalloy	78.5Ni, 3.8Cr, 0.6Mn, 17.1 Fe	10,000	40,000	8,000	200	4,500
4–79 Mo Permalloy	79Ni, 4Mo, 0.6Mn, 16.4 Fe	20,000–22,000	72,000–80,000	8,700	200	5,000
Supermalloy	79 Ni, 5 Mo, 0.5 Mn, 15 Fe	125,000	800,000–1,000,000	8,000	—	—
Hymu 80	75–80 Ni, bal. Mo & Fe	20,000	90,000	7,000	—	2,500
Permendur	50 Co, 50 Fe	800	5,000	24,500	12,000	14,000
2V Permendur	49 Co, 2 V, 49 Fe	800	4,500	24,500	6,000	14,000
45-25 Perminvar	45 Ni, 25 Co, 0.6 Mn, 29.4 Fe	365–400	1,800–2,000	15,500	4,000	3,300
Mo Perminvar	45 Ni, 25 Co, 7.5 Mo, bal. Fe	550	3,800	10,300	—	—
7–70 Perminvar	70 Ni, 7 Co, 0.6 Mn, 22.4 Fe	850	4,000	18,000	—	2,400
Heusler Alloy	61 Cu, 26 Mn, 13 Al	—	250	5,500	—	—
MAGNETIC POWDERS:						
Iron Powder	98.1–99.8 Fe	3.1–75	—	—	—	—
81 Permalloy Powder	81 Ni, 2 Mo, 17 Fe	75–125	130	—	—	—
Sendust Powder	9 Si, 5 Al, 85 Fe	30,000	120,000	10,000	100	5,000

Magnet Steels, Cast Magnets, Magnetic Alloys and Sintered Magnets

Tensile Strength (as used) *lb/sq in.*	Transverse Modulus of Rupture *lb/sq in.*	Hardness (as used) BR-Brinell (RC-Rockwell)	Remarks
ϕΔ300,000	——	ϕ60–65 RC	1
ϕΔ300,000	——	ϕ60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
Δ300,000	——	60–65 RC	
4,000	13,900	45 RC	2
4,000	13,900	45 RC	
4,000	13,900	45 RC	
3,000	7,200	45 RC	
3,000	7,200	45 RC	
3,000	7,200	45 RC	
12,000	22,500	45 RC	
12,000	22,500	45 RC	
12,000	22,500	45 RC	
9,000	24,000	45 RC	
9,000	24,000	45 RC	
5,450	10,500	50 RC	
23,000	45,000	56 RC	
23,000	45,000	56 RC	
39,500	50,000	58 RC	
10,500	23,000	45 RC	
65,000	70,000	43 RC	3
60,000	85,000	42 RC	
100,000	——	200 BR	4
100,000	——	200 BR	
100,000	——	200 BR	5
100,000	——	200 BR	
——	——	60 RC	6
nil	——	——	7
Δ110,000	——	230 BR	8
——	——	60 RC	9
200,000 (65% Red.) 360,000 (90% Red.)	——	60 RC	
103,000	——	210 BR	
——	——	——	
——	——	——	

1. So-called magnet steels, usually cast in ingots and hot-rolled into bars and strips. As-rolled hardness (depending upon section, steel, and treatment) varies from approximately 25 RC to approximately 55 RC and material is ordinarily suitable for hot forming and punching operations but not for cold forming or machining operations unless carbide tools are used. Material may be annealed to 25–35 Rockwell C in the case of cobalt steels, and to approximately 15 RC in all other cases. This will permit ordinary cold machining operations but the anneal is detrimental to magnetic properties and should be kept as light as possible. After forming, material is hardened (depending on steel) by either water or oil quench from hardening temperature. Intricate shapes may be cast.

2. So-called cast magnets. Unlike the magnet steels which are frequently formed and hardened by the consumer, the Alnicos are always provided in final form and heat-treated by the manufacturer. Grinding, which is the only finishing or machining operation practical, may be performed by either consumer or manufacturer. Cast of final shape in sand molds from induction furnaces, Alnico is a hard, weak, and brittle material but possesses sufficient strength for successful use in almost all permanent magnet applications. May be precision cast. Precipitation hardening alloys. Alnicos V and VI heat-treated in magnetic field possess properties indicated only in direction established by this field.

3. Same characteristics as cast Alnico except slightly stronger physically. Material manufactured by mixing component powders, pressing to final shape, and sintering. Most applicable to magnets one ounce or less in weight.

4. Ordinarily chill cast in the form of small bars, which may then be cold-rolled to strip and punched, or the bars may be machined and cut to size. (Material not hot workable as of date.) Material is reasonably malleable and ductile and readily machinable both before and after its final heat treatment (which will ordinarily be performed by the manufacturer). Intricate shapes may be precision cast or sand cast. Precipitation hardened alloy. As cast, hardness is 180BR. Magnets may also be sintered.

5. Sand cast in form of small bars and cold-drawn or rolled to wire or strip sizes. Magnetic properties depend upon severe cold reduction, and those specified are in direction of drawing or rolling only. Material is malleable, ductile, and machinable both before and after final heat treatment. Heat treatment performed by manufacturer. As cast, hardness is 135 BR. Material not hot workable.

6. Cast in ingot form and hot-rolled to bars and strips, which may then be hot-bent, hammered, sheared, punched, or cold-machined, but not cold-formed or rolled. As cast, hardness is 20–40 RC. A precipitation hardening alloy, it is heat-treated after forming or machining operations, after which it may be only ground. Quite fragile and brittle. Intricate shapes may be sand cast and machined before heat treatment.

7. Component oxides are mixed, pressed to final shape, and sintered in oxidizing atmosphere, after which material is heat-treated in a magnetic field. The magnetic properties indicated are in direction of this field only. Material very weak physically but may be ground with proper technique.

8. Cast in very small ingots, homogenized, and cold swaged or rolled (preferably swaged) to small bars. Material not hot-workable. Cold-working necessary to development of magnetic properties, although material not directional. A precipitation hardening alloy, it is heat-treated after swaging. Ductile, malleable, and machinable both before and after final heat treatment. Hardness as cast is 100 BR; after homogenizing or solution treatment—60 BR; after cold swaging—150 BR.

9. Ordinarily cast in form of small bars and hot-rolled to bars or strips. As cast or hot-rolled, hardness is 25–30 RC. Material may be readily hot or cold rolled, formed, or machined. Hardness after cold rolling is 40 RC. Precipitation hardening alloys. Heat-treated after rolling or machining, after which material may only be ground. Vicalloy II is severely cold reduced (usually to 0.002 inch tape) before heat treatment, and the magnetic properties indicated (which depend upon this treatment) are those in direction of rolling only.

* Directional magnetic properties.
‡ B_o = flux density at point of maximum energy product.
ϕ Intrinsic coercive force, H_{ci}.
Δ Approximate value only, for comparison purposes.
ϕ Value for hard outside shell. Softer core will have a lower value.

Magnetic, Physical and Mechanical Characteristics of Permanent

Permanent Magnet Alloy	Chemical Composition	Residual Flux Density B_R gauss	Coercive Force H_C oersteds	Maximum Energy Product $(BH)_{max}$	B_o‡ gauss	Density lb/cu in.	Mean Coefficient of Temperature Expansion (20C -300C) inches/inch/°C	Electrical Resistivity at 25C μohm cm
0.65% Carbon Steel	0.65 C, 0.85 Mn, bal. Fe	10,000	42	180,000	6,500	0.283	$13.3x10^{-6}$	18
1% Carbon Steel	1 C, 0.50 Mn, bal. Fe	9,000	51	200,000	5,900	0.282	$12.4x10^{-6}$	20
5% Tungsten Steel	5 W, 0.70 C, bal. Fe	10,500	70	330,000	7,000	0.292	$13.5x10^{-6}$	23
6% Tungsten Steel	6 W, 0.70 C, 0.50 Mn, 0.50 Cr, bal. Fe	9,500	74	330,000	6,500	0.294	$14.5x10^{-6}$	30
1% Chrome Steel	0.90 Cr, 0.60 C, 0.45 Mn, bal. Fe	9,500	52	230,000	6,500	0.282	$13.4x10^{-6}$	23
2% Chrome Steel	2.15 Cr, 0.90 C, bal. Fe	9,300	60	260,000	6,300	0.282	$13.1x10^{-6}$	23
3½% Chrome Steel	3.5 Cr, 1 C, 0.50 Mn, bal. Fe	9,500	66	290,000	6,500	0.281	$12.6x10^{-6}$	29
6% Chrome Steel	6 Cr, 1.1 C, 0.40 Mn, bal. Fe	9,500	74	300,000	6,200	0.281	$12.2x10^{-6}$	34
9% Cobalt Steel	9 Co, 0.90 C, 1.25 W, 5 Cr, bal. Fe	7,800	122	410,000	5,100	0.286	$14.0x10^{-6}$	30
17% Cobalt Steel	17 Co, 0.70 C, 8.25 W, 2.5 Cr, bal. Fe	9,000	170	650,000	5,900	0.302	$15.9x10^{-6}$	28
36% Cobalt Steel	36 Co, 0.80 C, 3.75 W, 5.75 Cr, bal. Fe	9,600	228	930,000	6,300	0.296	$17.2x10^{-6}$	27
40% Cobalt Steel	40 Co, 0.70 C, 5 W, 4.25 Cr, bal. Fe	10,000	242	1,030,000	6,500	0.296	$17.4x10^{-6}$	25
Alnico IA	12 Al, 22.5 Ni, 5 Co, bal. Fe	6,600	540	1,400,000	4,100	0.249	$12.6x10^{-6}$	75
Alnico IB	12 Al, 21 Ni, 5 Co, bal. Fe	7,100	450	1,400,000	4,700	0.249	$12.6x10^{-6}$	75
Alnico IC	12 Al, 19.5 Ni, 5 Co, bal. Fe	7,600	400	1,400,000	5,200	0.249	$12.6x10^{-6}$	75
Alnico IIA	10 Al, 18 Ni, 12.5 Co, 6 Cu, bal. Fe	7,000	630	1,600,000	4,200	0.256	$12.4x10^{-6}$	65
Alnico IIB	10 Al, 17 Ni, 12.5 Co, 6 Cu, bal. Fe	7,500	560	1,600,000	4,600	0.256	$12.4x10^{-6}$	65
Alnico IIC	10 Al, 16 Ni, 12.5 Co, 6 Cu, bal. Fe	8,000	425	1,600,000	5,500	0.256	$12.4x10^{-6}$	65
Alnico IIIA	12 Al, 26 Ni, bal. Fe	6,500	560	1,350,000	4,000	0.249	$13.0x10^{-6}$	63
Alnico IIIB	12 Al, 25 Ni, bal. Fe	7,000	470	1,350,000	4,500	0.249	$13.0x10^{-6}$	63
Alnico IIIC	12 Al, 24 Ni, bal. Fe	7,500	400	1,350,000	5,000	0.249	$13.0x10^{-6}$	63
Alnico IVA	12 Al, 28 Ni, 5 Co, bal. Fe	5,500	730	1,250,000	3,100	0.253	$13.1x10^{-6}$	75
Alnico IVB	12 Al, 27 Ni, 5 Co, bal. Fe	6,000	660	1,300,000	3,400	0.253	$13.1x10^{-6}$	75
*Alnico V	8 Al, 14 Ni, 24 Co, 3 Cu, bal. Fe	12,700	650	5,500,000	10,400	0.264	$11.3x10^{-6}$	47
*Alnico VIB	8 Al, 15 Ni, 24 Co, 3 Cu, 1 Ti, bal. Fe	10,500	760	3,650,000	7,100	0.268	$11.4x10^{-6}$	50
*Alnico VIC	8 Al, 15 Ni, 24 Co, 3 Cu, 0.5 Ti, bal. Fe	11,000	700	4,000,000	7,900	0.268	$11.4x10^{-6}$	50
Alnico XII	6 Al, 18 Ni, 35 Co, 8 Ti, bal. Fe	6,100	1,000	1,650,000	3,200	0.264	$11.0x10^{-6}$	62
Nipermag	12 Al, 30 Ni, 0.4 Ti, bal. Fe	5,600	660	1,340,000	3,400	0.249	$13.0x10^{-6}$	66
Sintered Alnico II	10 Al, 17 Ni, 12.5 Co, 6 Cu, bal. Fe	7,200	550	1,500,000	4,400	0.249	$12.4x10^{-6}$	68
Sintered Alnico IV	12 Al, 28 Ni, 5 Co, bal. Fe	5,500	730	1,250,000	3,100	0.232	$13.1x10^{-6}$	68
Cunico I	50 Cu, 21 Ni, 29 Co	3,400	710	850,000	2,000	0.300	—	24
Cunico II	35 Cu, 24 Ni, 41 Co	5,300	450	990,000	3,100	0.300	—	24
*Cunife I	60 Cu, 20 Ni, 20 Fe	5,700	590	1,850,000	4,200	0.311	—	18
*Cunife II	50 Cu, 20 Ni, 2.5 Co, 27.5 Fe	7,300	260	780,000	4,700	0.311	—	18
Remalloy; Comol	12 Co, 17 Mo, bal. Fe	10,000	230	1,100,000	6,900	0.295	—	45
*Vectolite	30 Fe_2O_3, 55 Fe_3O_4, 26 Co_2O_3	1,600	900	500,000	940	0.113	—	$225x10^6$
Silmanal	86.75 Ag, 8.8 Mn, 4.45 Al	590	6,300#	83,000	292	0.325	$\Delta 20.5x10^{-6}$	26
Vicalloy I	9.5 Va, 38.5 Fe, 52 Co	9,000	300	1,000,000	5,500	0.296	$11.2x10^{-6}$	60
*Vicalloy II	13 Va, 35 Fe, 52 Co	10,000	450	3,000,000	8,200	0.293	$11.2x10^{-6}$	60
Platinum Alloys	77.8 Pt, 22.2 Fe	5,830	1,570	3,070,000	3,400	—	$\Delta 10.2x10^{-6}$	—
	76.7 Pt, 23.3 Co	4,500	2,700	4,000,000	2,600	—	$\Delta 11.4x10^{-6}$	42
New KS	3.7 Al, 17.7 Ni, 27.2 Co, 6.7 Ti, bal. Fe	7,150	785	2,030,000	4,300	Δ0.268	$\Delta 11.7x10^{-6}$	Δ55

METALS AND ALLOYS . . .

Compositions that are especially intended and commonly used for solders, resistors, switches and contacts, thermocouples, and electronic tube parts

WITH about forty elements that are commonly used in forming alloys and as many ways for processing and treating them, there can be—and in fact are—virtually a limitless number of alloys. Some are suitable for many purposes, others are best used for the specific applications for which they have been developed or experience has found them most suited. Those alloys having properties that specifically suit them to applications peculiar to the electronic industry are listed here with brief information on their composition and unique uses.

Structural sheet steels and aluminum alloys, although among those materials used in great bulk, have been omitted from this list because they are used solely for mechanical purposes. Magnetic materials, being of special importance, are covered in a separate listing elsewhere in this directory. Metals used for conductors are, almost exclusively, highly pure copper, aluminum, or, for limited use, gold and silver. Their properties are given in detail in handbooks and need not be repeated here.

The listing consists of tables for the several outstanding electronic applications of metals and alloys. The alloys in each table are arranged in order of their composition, thus bringing together those having roughly similar properties. It is beyond the scope of a general compilation such as this one to include detailed data on characteristics. Additional information can be obtained from engineering handbooks and especially from "Engineering Alloys" by N. E. Woldman and R. J. Metzler, American Society for Metals, which lists practically all regularly available compositions, their mechanical properties and manufacturers, and from "Materials Handbook" by G. S. Brady, McGraw-Hill Book Co., which describes the composition, properties and uses of numerous materials both metals and nonmetals, or directly from manufacturers.

RESISTANCE AND HEATER ELEMENT ALLOYS

Name	Composition, Approximate Percent	Properties and Remarks
Alloys of Nickel		High-temperature heating elements, hot-operating resistors, corrosion resistant
Silicon Nickel	95 Ni, 2.5 Si, 215 Mn	
Magno (Elalco)	95 Ni, 5 Mn	
D-H Nickel A, D, E, Z	Ni	
Abros	88 Ni, 10 Cr, 2 Mn	Stainless and corrosion resistant
Kromore, Rayo, Red Ray	85 Ni, 15 Cr	
Brightray, Pyromic, Kromax, Cromaloy IV, Superior A Nickel Chrome	80 Ni, 20 Cr	Can be used up to 1,100 C
Chromel	Ni – Cr alloy	Chromel A is for use as a heating element between 1,400 and 2,100 F, corrosion resistant (80 Ni, 20 Cr); Chromel C (60 Ni, 16 Cr, 24 Fe) resists corrosion and heat to 1,900 F; Chromel D (35 Ni, 18 Cr, 47 Fe) to 2,000 F; Chromel P (90 Ni, 10 Cr) has high resistance to heat to 2,400 F
Glowray	65 Ni, 15 Cr, 20 Fe	Similar to Chromel C
Tophet	Ni – Cr alloy	Tophet A (77 – 79 Ni, 19 – 20.5 Cr, 0.15 max C, 2 Mn) is tough to machine, can be used to 2,100 F; Tophet C (57 Ni, 15 Cr, 0.15 max C, rest Fe) resists some common acids, can be used to 1,850 F
Superior	78 Ni, 19.5 Cr, 2 Mn, 0.5 Fe	
Chromnickel, Chrome Nickel	77 Ni, 20 Cr, 2 Mn	For use to 1,000 C; Chrome Nickel Iron (70 Ni, 20 Cr, 8 Fe, 2 Mn) can be used to 1,150 C
Stitching Wire	74.5 Ni, 18 Cr, 7.5 Mn	
Nichroloy	Ni-Cr-Mn-Fe alloys	Nichroloy I (23 Ni, 20 Cr, Mn, V, Al, about 45 Fe), Nichroloy II (40 Ni, 7 Cr, 3 Mn, 50 Fe), Nichroloy III (75 Ni, 16 Cr, 3 Mn, 6 Fe)
Mond Metal	70 Ni, 26 Cu, 4 Mn	Resistance wire in chemical and mining machinery
Hytemco	70 Ni, 30 Fe	Immersion heaters, max. operating temp. 500 C
Jeliff Alloy	Nickel alloys	J. A. C. (80 Ni, 20 Cr) industrial furnace elements, voltmeter windings, high resistance to oxidation and corrosion, max. operating temp. 2,100 F; J. A. C. (60 Ni, 15 Cr, 25 Fe) heating elements, rheostats, potentiometers, heat and corrosion resistant, max. operating temp. 1,700 F; J. A. D. (30 Ni, 5 Cr, 65 Fe) heavy rheostats, max. operating temp. 1,300 F; J. A. 70 (70 Ni, 30 Cu) max. operating temp. 1,100 F

RESISTANCE AND HEATER ELEMENT ALLOYS

Name	Composition, Approximate Percent	Properties and Remarks
Lucerno	68 – 65 Ni, 27 – 30 Cu, 0 – 2.4 Fe, 2.2 – 5 Mn	
Chroman Alloys	Ni-Cr alloys	Acid—resisting heating elements
Lucero	Ni-Cu alloy	(70 Ni, 30 Cu) springs, electrical resistances, resists heat to 500 C; (65 Ni, 30 Cu, 5 Mn) springs, electrical resistances, resists corrosion
Calomic	65 Ni, 15 Cr, 20 Fe	
Cronits	63.55 Ni, 20.32 Fe, 13.72 Cr, 1.04 Mn, 0.8 Al, 0.43 Si	Max. operating temp. 1,000 C
Calido (Elalco), Cromaloy	60 – 64 Ni, 8 – 16 Cr, 24 – 25 Fe, (3 – 4 Mn)	Grade made without Mn resists oxidation up to 1,000 C, with 4 Mn good to 950 C
Premier C	60 Ni, 24 Fe, 16 Cr	Resistances up to 1,700 F
Placet	60 Ni, 20 Fe, 15 Cr, 5 Mn	
Cronit	60 Ni, 40 Cr	
Bario	57.4 Ni, 21.4 Cr, 1 Fe	Stainless and corrosion-resisting resistors
D-H Nickel A, D, E, Z	Ni alloy	
Nichromes		Heating elements, resistances, corrosion resistant
Nichrome I	65 Ni, 11.18 Cr, 22.36 Fe, 0.7 Mn, 0.26 Si	
Nichrome II	66 Ni, 22 Cr, 22 Fe	Max. operating temp. 1,100 C
Nichrome III	85 Ni, 15 Cr	Coef. resis. 0.000187, sp. resis. 89.5
Nichrome IV, V	80 Ni, 20 Cr	Max. operating temp. 1,100 C
Nichrome Type A	62 Ni, 15 Cr, 23 Fe	Type B is used in alloying other metals
Nichrome S	25 Ni, 15 Cr, 60 Fe	
Wrought Nichrome	62 Ni, 15 Cr, 0.12 C, rest is Fe	Coef. exp. in range 0 to 20 C: 0.00017
Cast Nichrome	60 Ni, 13 Cr, 0.7 C, rest is Fe	Coef. exp. in range 20 to 500 C: 0.0000141
Irons		Low-temp. heating elements, high resistances
Allegheny Ohmaloy	12 – 14 Cr, 4 – 4.5 Al, 0.5 max. Ni, 0.12 max. C, rest is Fe	Corrosion resistant, for chemical equipment
Fercaloy, Alcres	83 Fe, 13 Cr, 4 Al	
Phenix	75 Fe, 25 Ni	
Kruppin, Vestalin	About 70 Fe, 28 Ni, C	
Alchrome 6	19 – 21 Cr, 5125 – 6.5 Al, rest Fe	Resists sulphur
Kanthal A	68.4 Fe, 23.4 Cr, 6.2 Al, 1.9 Co, 0.06 C	Resists oxidation, brittle when cold, tough when hot, made also in grades A-1 and D which are plastic when hot
Tico	27.5 – 30.4 Ni, 1.12 Mn, 1.1 Cu, rest Fe	
Comet	65 Fe, 30 Ni, 5 Cr	Max. operating temp. 700 C; with Mn and Cu added if heavy-duty rheostats are to be made from it
Dullray, Frigida'	64 – 60 Fe, 33 – 35 Ni, 3 – 5 Cr	For temperatures below a dull red, resistances, coef. exp. in range 0 – 40 C: 0.0000015
Cromin D	30 Ni, 64 Fe, 4 – 7 Cr, Mn, C	Also known as Comet (see above) and No. 193 Alloy
Smith No. 10, Alloy No. 10	55 Fe, 37.5 Cr, 7.5 Al	Max. operating temp. 2,400 F, high resistance
Zorite	35 Ni, 17 – 15 Cr, 1.75 Mn, 0.5 C, 1 Si, rest Fe	Resists heat and corrosion up to 1,900 F
D-H No. 525 Alloy	35 Ni, 16 Cr, 49 Fe	Resistors for high temperatures, heat resistant to 800 C, sp. resis. 100
Alphate	Aluminum coated steel	Electrical resistance wire resists corrosion
Copper Alloys		Low temp. low resis. for instruments and precision potentiometers
Radio Alloy D-H 30 & 90 Ohm Alloy	Cu-Ni and Ni alloys	No. 30 (98 Cu, 2 Ni) max. working temp. 350 C; No. 60 (95 Cu, 5 Ni) similar to No. 30; No. 90 (88 Cu, 12 Ni) max. temp. 400 C; No. 180 (95 Ni, 2.5 Si, 2.5 Mn) max. temp. 400 C, all types used in electrical instruments and resistors
Lohm, D-H Lohm	7 – 7.5 Ni, rest Cu	Low electrical resist., max. temp. 200 C
Ohmal	87.5 Cu, 9 Mn, 3.5 Ni	
Therlo	85 Cu, 13 Mn, 2 Al	
Lunge Resistance, Resistin, Rheotan No. 1 – 3	Cu, Mn, Fe, Zn	Compositions of different types are different, but all used as resistances
Manganese Copper A-H	85 – 30 Cu, 8 – 52 Mn, 1 – 10 Fe, others	Heat and corrosion resistant
Midohm	77 – 78 Cu, 22 – 23 Ni	Heat resistant to 200 C, rheostats
Copper Nickel 30%	70 – 67 Cu, 30 – 33 Ni	Corrosion-resistant resistors
Newloy	64 Cu, 35 Ni, 1 Sn	Corrosion and acid resistant
Nickelin	85 – 54 Cu, 15 – 30 Ni, 0 – 20 Zn, (3 Mn)	Heavy-duty resistors, max. operating temp. 500 C, some grades contain traces of Fe

METALS AND ALLOYS . . .

Compositions that are especially intended and commonly used for solders, resistors, switches and contacts, thermocouples, and electronic tube parts

WITH about forty elements that are commonly used in forming alloys and as many ways for processing and treating them, there can be—and in fact are—virtually a limitless number of alloys. Some are suitable for many purposes, others are best used for the specific applications for which they have been developed or experience has found them most suited. Those alloys having properties that specifically suit them to applications peculiar to the electronic industry are listed here with brief information on their composition and unique uses.

Structural sheet steels and aluminum alloys, although among those materials used in great bulk, have been omitted from this list because they are used solely for mechanical purposes. Magnetic materials, being of special importance, are covered in a separate listing elsewhere in this directory. Metals used for conductors are, almost exclusively, highly pure copper, aluminum, or, for limited use, gold and silver. Their properties are given in detail in handbooks and need not be repeated here.

The listing consists of tables for the several outstanding electronic applications of metals and alloys. The alloys in each table are arranged in order of their composition, thus bringing together those having roughly similar properties. It is beyond the scope of a general compilation such as this one to include detailed data on characteristics. Additional information can be obtained from engineering handbooks and especially from "Engineering Alloys" by N. E. Woldman and R. J. Metzler, American Society for Metals, which lists practically all regularly available compositions, their mechanical properties and manufacturers, and from "Materials Handbook" by G. S. Brady, McGraw-Hill Book Co., which describes the composition, properties and uses of numerous materials both metals and nonmetals, or directly from manufacturers.

RESISTANCE AND HEATER ELEMENT ALLOYS

Name	Composition, Approximate Percent	Properties and Remarks
Alloys of Nickel		High-temperature heating elements, hot-operating resistors, corrosion resistant
Silicon Nickel	95 Ni, 2.5 Si, 215 Mn	
Magno (Elalco)	95 Ni, 5 Mn	
D-H Nickel A, D, E, Z	Ni	
Abros	88 Ni, 10 Cr, 2 Mn	Stainless and corrosion resistant
Kromore, Rayo, Red Ray	85 Ni, 15 Cr	
Brightray, Pyromic, Kromax, Cromaloy IV, Superior A Nickel Chrome	80 Ni, 20 Cr	Can be used up to 1,100 C
Chromel	Ni – Cr alloy	Chromel A is for use as a heating element between 1,400 and 2,100 F, corrosion resistant (80 Ni, 20 Cr); Chromel C (60 Ni, 16 Cr, 24 Fe) resists corrosion and heat to 1,900 F; Chromel D (35 Ni, 18 Cr, 47 Fe) to 2,000 F; Chromel P (90 Ni, 10 Cr) has high resistance to heat to 2,400 F
Glowray	65 Ni, 15 Cr, 20 Fe	Similar to Chromel C
Tophet	Ni – Cr alloy	Tophet A (77 – 79 Ni, 19 – 20.5 Cr, 0.15 max C, 2 Mn) is tough to machine, can be used to 2,100 F; Tophet C (57 Ni, 15 Cr, 0.15 max C, rest Fe) resists some common acids, can be used to 1,850 F
Superior	78 Ni, 19.5 Cr, 2 Mn, 0.5 Fe	
Chromnickel, Chrome Nickel	77 Ni, 20 Cr, 2 Mn	For use to 1,000 C; Chrome Nickel Iron (70 Ni, 20 Cr, 8 Fe, 2 Mn) can be used to 1,150 C
Stitching Wire	74.5 Ni, 18 Cr, 7.5 Mn	
Nichroloy	Ni-Cr-Mn-Fe alloys	Nichroloy I (23 Ni, 20 Cr, Mn, V, Al, about 45 Fe), Nichroloy II (40 Ni, 7 Cr, 3 Mn, 50 Fe), Nichroloy III(75 Ni, 16 Cr, 3 Mn, 6 Fe)
Mond Metal	70 Ni, 26 Cu, 4 Mn	Resistance wire in chemical and mining machinery
Hytemco	70 Ni, 30 Fe	Immersion heaters, max. operating temp. 500 C
Jeliff Alloy	Nickel alloys	J. A. C. (80 Ni, 20 Cr) industrial furnace elements, voltmeter windings, high resistance to oxidation and corrosion, max. operating temp. 2,100 F; J. A. C. (60 Ni, 15 Cr, 25 Fe) heating elements, rheostats, potentiometers, heat and corrosion resistant, max. operating temp. 1,700 F; J. A. D. (30 Ni, 5 Cr, 65 Fe) heavy rheostats, max. operating temp. 1,300 F; J. A. 70 (70 Ni, 30 Cu) max. operating temp. 1,100 F

RESISTANCE AND HEATER ELEMENT ALLOYS

Name	Composition, Approximate Percent	Properties and Remarks
Lucerno	68 – 65 Ni, 27 – 30 Cu, 0 – 2.4 Fe, 2.2 – 5 Mn	
Chroman Alloys	Ni-Cr alloys	Acid—resisting heating elements
Lucero	Ni-Cu alloy	(70 Ni, 30 Cu) springs, electrical resistances, resists heat to 500 C; (65 Ni, 30 Cu, 5 Mn) springs, electrical resistances, resists corrosion
Calomic	65 Ni, 15 Cr, 20 Fe	
Cronits	63.55 Ni, 20.32 Fe, 13.72 Cr, 1.04 Mn, 0.8 Al, 0.43 Si	Max. operating temp. 1,000 C
Calido (Elalco), Cromaloy	60 – 64 Ni, 8 – 16 Cr, 24 – 25 Fe, (3 – 4 Mn)	Grade made without Mn resists oxidation up to 1,000 C, with 4 Mn good to 950 C
Premier C	60 Ni, 24 Fe, 16 Cr	Resistances up to 1,700 F
Placet	60 Ni, 20 Fe, 15 Cr, 5 Mn	
Cronit	60 Ni, 40 Cr	
Bario	57.4 Ni, 21.4 Cr, 1 Fe	Stainless and corrosion-resisting resistors
D-H Nickel A, D, E, Z	Ni alloy	
Nichromes		Heating elements, resistances, corrosion resistant
Nichrome I	65 Ni, 11.18 Cr, 22.36 Fe, 0.7 Mn, 0.26 Si	
Nichrome II	66 Ni, 22 Cr, 22 Fe	Max. operating temp. 1,100 C
Nichrome III	85 Ni, 15 Cr	Coef. resis. 0.000187, sp. resis. 89.5
Nichrome IV, V	80 Ni, 20 Cr	Max. operating temp. 1,100 C
Nichrome Type A	62 Ni, 15 Cr, 23 Fe	Type B is used in alloying other metals
Nichrome S	25 Ni, 15 Cr, 60 Fe	
Wrought Nichrome	62 Ni, 15 Cr, 0.12 C, rest is Fe	Coef. exp. in range 0 to 20 C: 0.00017
Cast Nichrome	60 Ni, 13 Cr, 0.7 C, rest is Fe	Coef. exp. in range 20 to 500 C: 0.0000141
Irons		Low-temp. heating elements, high resistances
Allegheny Ohmaloy	12 – 14 Cr, 4 – 4.5 Al, 0.5 max. Ni, 0.12 max. C, rest is Fe	Corrosion resistant, for chemical equipment
Fercaloy, Alcres	83 Fe, 13 Cr, 4 Al	
Phenix	75 Fe, 25 Ni	
Kruppin, Vestalin	About 70 Fe, 28 Ni, C	
Alchrome 6	19 – 21 Cr, 5125 – 6.5 Al, rest Fe	Resists sulphur
Kanthal A	68.4 Fe, 23.4 Cr, 6.2 Al, 1.9 Co, 0.06 C	Resists oxidation, brittle when cold, tough when hot, made also in grades A-1 and D which are plastic when hot
Tico	27.5 – 30.4 Ni, 1.12 Mn, 1.1 Cu, rest Fe	
Comet	65 Fe, 30 Ni, 5 Cr	Max. operating temp. 700 C; with Mn and Cu added if heavy-duty rheostats are to be made from it
Dullray, Frigida'	64 – 60 Fe, 33 – 35 Ni, 3 – 5 Cr	For temperatures below a dull red, resistances, coef. exp. in range 0 – 40 C: 0.0000015
Cromin D	30 Ni, 64 Fe, 4 – 7 Cr, Mn, C	Also known as Comet (see above) and No. 193 Alloy
Smith No. 10, Alloy No. 10	55 Fe, 37.5 Cr, 7.5 Al	Max. operating temp. 2,400 F, high resistance
Zorite	35 Ni, 17 – 15 Cr, 1.75 Mn, 0.5 C, 1 Si, rest Fe	Resists heat and corrosion up to 1,900 F
D-H No. 525 Alloy	35 Ni, 16 Cr, 49 Fe	Resistors for high temperatures, heat resistant to 800 C, sp. resis. 100
Alphate	Aluminum coated steel	Electrical resistance wire resists corrosion
Copper Alloys		Low temp. low resis. for instruments and precision potentiometers
Radio Alloy D-H 30 & 90 Ohm Alloy	Cu-Ni and Ni alloys	No. 30 (98 Cu, 2 Ni) max. working temp. 350 C; No. 60 (95 Cu, 5 Ni) similar to No. 30; No. 90 (88 Cu, 12 Ni) max. temp. 400 C; No. 180 (95 Ni, 2.5 Si, 2.5 Mn) max. temp. 400 C, all types used in electrical instruments and resistors
Lohm, D-H Lohm	7 – 7.5 Ni, rest Cu	Low electrical resist., max. temp. 200 C
Ohmal	87.5 Cu, 9 Mn, 3.5 Ni	
Therlo	85 Cu, 13 Mn, 2 Al	
Lunge Resistance, Resistin, Rheotan No. 1 – 3	Cu, Mn, Fe, Zn	Compositions of different types are different, but all used as resistances
Manganese Copper A-H	85 – 30 Cu, 8 – 52 Mn, 1 – 10 Fe, others	Heat and corrosion resistant
Midohm	77 – 78 Cu, 22 – 23 Ni	Heat resistant to 200 C, rheostats
Copper Nickel 30%	70 – 67 Cu, 30 – 33 Ni	Corrosion-resistant resistors
Newloy	64 Cu, 35 Ni, 1 Sn	Corrosion and acid resistant
Nickelin	85 – 54 Cu, 15 – 30 Ni, 0 – 20 Zn, (3 Mn)	Heavy-duty resistors, max. operating temp. 500 C, some grades contain traces of Fe

RESISTANCE AND HEATER ELEMENT ALLOYS

Name	Composition, Approximate Percent	Properties and Remarks
Nickel Silver		Corrosion-resistant wire
Grade A	65 Cu, 18 Ni, 17 Zn	
Grade B	55 Cu, 18 Ni, 27 Zn	
Zodiac	64 Cu, 20 Ni, 16 Zn	
Scovill No. 100	64 Cu, 18 Ni, 18 Zn	
105	64 Cu, 10 Ni, 26 Zn	
German Silver		(U. S. Bu. Stds. G. S. is 61.6 Cu, 21.1 N, 17.2 Zn)
Nickelin	58 Cu, 22 Ni, 20 Fe	(Nickelin Resistance is 54 Cu, 20 Zn, 26 Ni)
Common Formula	55 Cu, 25 Zn, 20 Ni	
Firsts A Special	56 Cu, 17 Ni, 27 Zn	
French Alloy	58 – 50 Cu, 25 – 30 Zn, 17 – 20 Ni	
Copel, Cunic	55 Cu, 45 Ni	Resistance alloy for use up to 800 F
Konstantan	54 Cu, 45 Ni, 1 Mn	Precision resistances, max. operating temp. 600 C, melting point (in case one treats precision resistors rough) 1,276 C

Solders

Name	Approximate Composition in Percent	Melting Pt, Remarks
Standard Compositions		
S. A. E. Solders		
No. 1A	44–45 Sn, 0.4 max Sb, rest Pb	Melts 361–414 F
No. 1B	43–43.5 Sn, 1.5–2 Sb, rest Pb	Melts 361–405 F
No. 2A	39–40 Sn, 0.4 max Sb, rest Pb	Melts 361–460 F
No. 2B	38–38.5 Sn, 1.5–2 Sb, rest Pb	Melts 361–450 F
No. 3A	29–30 Sn, 0.4 max Sb, rest Pb	Melts 361–494 F
No. 3B	28–28.5 Sn, 1.5–2 Sb, rest Pb	Melts 361–484 F
No. 4A	24–25 Sn, 0.4 max Sb, rest Pb	Melts 361–511 F
No. 4B	24–25 Sn, 1.25–1.75 Sb, rest Pb	Melts 361–502 F
A. S. T. M. (Spec. B–32–31) Class A		
Grade 0	63 Sn, 37 Pb, 0–0.12 Sb, 0.08 Cu	
Grade 1	50 Sn, 50 Pb, 0–0.12 Sb, 0.08 Cu	
Grade 2	45 Sn, 44 Pb, 0–0.12 Sb, 0.08 Cu	
Grade 3	40 Sn, 60 Pb, 0–0.12 Sb, 0.08 Cu	
Grade 4	37.5 Sn, 62.4 Pb, 0–0.12 Sb, 0.08 Cu	
Grade 5	33 Sn, 67 Pb, 0–0.12 Sb, 0.08 Cu	
A. S. T. M. (Spec. B–32–31) Class B		
Grade 1	49.25 Sn, 50 Pb, 0–0.75 Sb, 0–0.15 Cu	
Grade 2	43.5 Sn, 55 Pb, 0–1.5 Sb, 0–0.15 Cu	
Grade 3	38 Sn, 60 Pb, 0–2 Sb, 0–0.15 Cu	
Grade 4	35.5 Sn, 62.5 Pb, 0–2 Sb, 0–0.15 Cu	
Grade 5	31 Sn, 67 Pb, 0–2 Sb, 0–0.15 Cu	
U. S. Bureau of Standards Aluminum Solders		
B of S N–1	78 Sn, 9 Al, 8 Zn, 5 Cd	
B of S N–2	69 Sn, 2.4 Al, 26 Zn, 2.4 P	
B of S N–3	86 Sn, 5 Al, 9 Zn, 0.25 P	
B of S N–4	86 Sn, 5 Al, 9 Zn	
B of Z N–1	75 Zn, 60 Cd, 4 Al	
Commercial Compositions		
Lead Bases		Commercial lead is 99.93 Pb, 0.06 Cu, noncorrosive in air and water, melts at 621 F
Dippit	94.5 Pb, 5 Sn 0.5 Cu	High melting point
Al. Solder	92 Pb, 8 Cd	
Mystic Metal	89 Pb, 11 Sn, 0.1 Bi	
Cadmium Sldr.	80–90 Pb, 5–10 Sn, 5–10 Cd	With 90 Pb, melts at 264 F
Bohn 10–90 to 60–40	90–40 Pb, 10–60 Sn, 0.5 max Sb	No. 10–90 (10 Sn, 90 Pb) melts at 310 F, others melt at 358 F

Solders

Name	Approximate Composition in Percent	Melting Pt, Remarks
Waraloy 20X	78.75 Pb, 20 Sn, 1.25 Ag	Melts at 440 to 490 F
Non-Pareil	78 Pb, 17 Sb, 5 Sn	Melts at 300 C
Comm. lead Sldr. No. 1	68–57 Pb, 30–40 Sn, 2–3 Sb	Melts at about 400 F
ST–10, 15, 20, 30 Sldr.	67–87 Pb, 30–10 Sn, 1.25–1.5 Ag	Various grades melt at from 478 to 554 F
Plumbers Sldr.	67 Pb, 33 Sn	Soft solders, various
Richloy Hi–Tensil Sldr.	70–35 Pb, 30–65 Sn	grades melt at from 356 to 416 F
Wiping Sldr.	60 Pb, 40 Sn	Melts at 446 F
Ajax Honest, Half and Half, Sldr. No. 2	50 Pb, 50 Sn	Melts at 446 F
Tin Bases		Tin melts at 449 F
Gr. Silver Solder	75 Sn, 10 Ag, 3 Cu, 2 Zn	
Tinman's & Slicker Solders	66 Sn, 34 Pb	Melts at 356 F
Sterling	62 Sn, 15 Zn, 11 Al, 8.3 Pb, 2.5 Cu, 1.2 Sb	
Bismuth Solder	33–50 Sn, 33–25 Pb, 33–25 Bi	
Tin Base Solders for Alumium		Al melts at 1,220 F
Wilmott's	86 Sn, 14 Bi	
Wagner & Guhrs	80 Sn, 20 Zn	
Al. Sldrs.	78 Sn, 9 Al, 8 Zn, 5 Cd	
Burgess	76 Sn, 21 Zn, 3 Al	
Richards	71.5 Sn, 25 Zn, 3.5 Al	
Grimm's (A)	69.1 Sn, 28.8 Pb, 1.44 Zn, 0.72 Ag	
Al. Sldr. (D)	67.5 Sn, 16.5 Zn, 15 Al, 1 Cu	
Frismuth (C)	67 Sn, 27 Pb, 3 Al	
Al. Sldr	56.4 Sn, 37.6 Zn, 3 Cu, 3 Al	
Al. Sldr. (A)	56 Sn, 30 Zn, 5 Bi	
Lo–Luminum Solder	55 Sn, 33 Zn, 11 Al, 1 Cu	
Al. Sldr. (E)	53 Sn, 40 Zn, 7 Al	
Grimm's (B)	50 Sn, 25 Pb, 25 Zn	
Al. Sldr.	41 Sn, 28 Zn, 3 Cu, 0.6 Mn, 0.1 Al	
Zinc Bases		Zinc melts at 787 F
Al. Sldr.	90 Zn, 6 Al, 4 Cu	Carnegie Institute alloy(Geophysical Lab.)
Mourey Al. Solder	94–80 Zn, 2–8 Cu, 4–12 Al	
Zelco	83 Zn, 15 Al, 2 Cu	Aluminum solder
Bourbouse Al. Sldr.	81.82 Zn, 18.18 Al	

Solders

Name	Approximate Composition in Percent	Melting Pt, Remarks
Argentan Solder	57 Zn, 35 Cu, 8 Ni	
Al. Sldr. (C)	57 Zn, 33 Sn, 12.5 Pb, 2 Sb	
Aalener Zinc Alloy	51.4 Zn, 21.6 Pb, 20.5 Sn, 3.5 Cu, 3 Sb	
Cornande & Cruiys Al. Solder	52 Zn, 30 Sn, 17.5 Al, 0.5 Ni	
Wuest No. 1	50 Zn, 30 Al, 20 Cu	Aluminum solder
No. 2	65 Zn, 20 Al, 15 Cu	Aluminum solder
Refractory Solder	50 Zn, 50 Cu	
Roesch	50 Zn, 49 Sn, 0.7 Sb, 0.2 Cu	
Al. Sldr. (B)	50 Zn, 33 Sn, 12.5 Pb, 2 Sb	
Frismuth (A)	47.5 Zn, 31.5 Sn, 10.5 Al, 5.5 Cu, 5.5 Ag	
(B)	47.4 Zn, 36.8 Sn, 10.5 Al, 5.3 Cu	
Silver Base Solders		Ag melts at 1,761 F
Hard Silver Solder: 80 Ag, 13 Cu, 6.8 Zn		
Sterling Silver Solder: 80 Ag, 18 Zn, 2.5 Cu		
Weiger: 80–77 Ag, 18–20 Cu, 2–5 Pt		
Medium Silver Solder: 75–70 Ag, 20–23 Cu, 5–7.5 Zn		
Platinum Solder: 73 Ag, 27 Pt		
Pure Silver Solder: 72 Ag, 28 Cu		
French Silver Solder: 66 Ag, 23 Cu, 10 Zn		
Common Silver Solder: 62.5 Ag, 30 Cu, 7.5 Zn		
Quicksilver Sldr.: 63–57 Ag, 21–25 Cu, 3–7 Sn, 10–12 Zn		
White Gold Solder: 55 Ag, 30 Au, 12 Zn, 1 Cu		
Wilco Silver Solders: 22–65 Ag, 44–25 Cu, 34–10 Zn		
Silver Solder: 32 Ag, 23 Cu, 17 Zn, 18 Cd		

Solders

Name	Approximate Composition in Percent	Melting Pt, Remarks
Copper Base and Other Types		Copper melts at 1,981 F
Imitation Gold	97.8 Cu, 2 Al, 0.2 Au	Gold solder
Gold Metal Leaf	84–66 Cu, 16–34 Zn, 0.4 Pb max	Gold solder
Deletots Alloy	80 Cu, 18 Zn, 2 Mn	Brass solder, ductile
Hard Yellow Solder	58 Cu, 43 Zn, 1.23 Sn, 0.3 Pb	
Hard Solder	57–50 Cu, 43–50 Zn	
Minargent	57–46 Cu, 40–32 Ni, 28–0 W, 0.2–0.5 Al	Silver solder
Gr. Silver Solder	40–30 Cu, 40–30 Zn, 10–20 Ag, 20 Cd	Silver solder
Odessa	42.5 Cu, 33.25 Ag, 15.75 Zn, 8.5 Ni	Silver solder
Handy Silver Solder: Cu, Ag, Zn in various percents for grades ranging in melting point from 1,325 to 1,600 F; special purpose grades include those for parts under strain, solders for Cu, Ni, Monel, stainless steel and brass		
Gold Sldr., White Gold Solder	Au, Ag, Cu, Ni, Cd	Zn in various percents depending on grade and carat
Cazin	82.6 Cd, 17.4 Zn	Solder for steel, melts at 263 C
Bates Al. Solder	70 Al, 30 Zn	

THERMOCOUPLE ALLOYS

Name	Composition, Approximate Percent	Outstanding Characteristics and Remarks
Copper and Nickel Alloys		Constant resistance alloys, little affected by temperature, for use in nonsensing portions of thermocouple circuits
Manganin	85 – 86 Cu, 9 – 12 Mn, 3 – 4 Ni	High resistivity and low temp. coef. of resistance, low thermal emf
Nickelene	80 – 52 Cu, 5 – 30 Ni, 10 – 35 Zn	German silver
Constantan	60 – 45 Cu, 40 – 55 Ni	Resist effects of heat to 2,200 F (Constantan, in addition to being made with various percentages of copper and nickel, is made in grades having small percentages of other metals to provide special properties)
Eureka	60 Cu, 40 Ni	
Ideal	58 – 53 Cu, 40 – 45 Ni, Fe, Mn, Al	
Ferry	56 – 55 Cu, 44 – 45 Ni	
Cupron	55 Cu, 45 Ni	
Advance	54 – 56 Cu, 44 – 46 Ni	
Plantinoid A	60 Cu, 14 Ni, 24 Zn, 2 W	Tungsten German silver
Plantinoid B	54 Cu, 25 Ni, 20 Zn, 1 W	
Ia-Ia	60 – 58 Cu, 40 – 42 Ni, 1 Fe and Mn	Negligible temperature coefficient of resistance
Copper-Nickel 40%	60 – 55 Cu, 40 – 45 Ni	
Jelliff Alloy 45	55 Cu, 45 Ni	Very low temp. coef. of resistance, resists oxidation and corrosion at low temp., max. operating temp. 950 F
Cunic	55 Cu, 45 Ni	
D-H No. 11 Alloy	Cu and Ni	
Nickel and Manganese or Chromium Alloys		Temperature-sensitive elements for use in sensing portions of thermocouple circuits
Mangonic	97 Ni, 3 Mn	
Alumel	95 Ni, Mn, Al, Si	Negative thermocouple element, max. operating temp. 2,400 F
Chromel P	90 Ni, 10 Cr	Resists effects of heat to 2,400 F, high electrical resistance, positive thermocouple element
Nickel C	85 Ni, 15 Mn	Resists heat and corrosion from salt solutions and caustics
Chronin 85	85 Ni, 13 Cr, Cu, Fe, Mn, Al, impurities	Thermocouple against Ni
Chronin 100	80 Ni, 18 Cr, Cu, Fe, Mn, Al	Heat resistant to 1,200 C (see Chronin 85)
Imphy A.T.E., B.T.E., and C.T.E.	Ni alloys	Imphy B.T.E. used as thermocouple element against Imphy A.T.E. or C.T.E., or nickel; the combination with Imphy C.T.E. gives a useful range from − 220 C to + 700 C

METALS FOR ELECTRICAL SWITCHES AND CONTACTS

Name	Composition, Approximate Percent	Ultimate Tensile Strength in lb/sq in	Applications and Remarks
Red Bronzes			Spring type contacts
Electronics Bronze	98.75 Cu, 1.25 Sn	77,000	Springs, contacts, diaphragms
Government Bronze	95 Cu, 5 Sn	50,000	
Riverside No. 105	95 Cu, 4 Zn, 1 Sn	38,000	Fuse clips, electrical contacts, 38% conductivity
Spring Oreide	92 Cu, 8 Sn	55,000	Spring contacts, switches, diaphragms
Sheet Gun Metal	90 Cu, 10 Sn	———	Corrosion resistant electrical contacts
Lubaloy	90 Cu, 1.75 Sn, 8.25 Zn	81,000	Contact springs, radio tube sockets
Phosphor Bronzes			Spring contacts requiring hard surfaces
Super-X, Grade A, E	96.5 Cu, 3.5 Sn, P	79,500–	Fuse clips, springs, switches, diaphragms
Omega Brand, No. 30	95.5 Cu, 4.3 Sn, 0.2 P	160,000	Light springs and contacts
Riverside No. 30	94.4 min Cu, 3.8 – 4.8 Sn, 0.05 – 0.35 P, 0.3 Zn	88,000– 40,000	Light springs and contacts, resists corrosion from salt water, Brinell hardness No. 100
Hard Phosphor Bronze	92.8 Cu, 7 Sn, 0.2 P		
Super-X, Grade C	92 Cu, 8 Sn, P	93,500– 57,000	Spring contacts requiring good fatigue resistance
Riverside No. 47	91 min Cu, 7.5 – 8.5 Sn, 0.05 – 0.25 P, 0.2 Zn	101,000– 53,000	Spring contacts, fuse clips, used to meet Severe forming and endurance requirements Resists salt water corrosion
Other Copper Alloys			
Anaconda Beryllium Copper	2 – 2.25 Be, 0.25 – 0.5 Ni, rest is Cu	196,000– 50,000	Springs, high fatigue and strong parts, Fuse clips, switch blades
Beraloy No. 25	97.75 Cu, 2 Be, 0.25 Co	175,000– 66,000	Springs, electrical contacts, valve diaphragms
Silvel	Cu, Zn, and Ni or Mn and Sn, and Fe	130,000– 73,000	German silver, electrical contact springs
Super-X 18% Nickel Silver Grade B	55 Cu, 18 Ni, 27 Zn	99,500– 50,000	Tarnish resistant springs and switch blades
Best German Silver	50 – 46 Cu, 31 – 20 Ni, 34 – 29 Zn		
Cupaloy	Cu – Cr alloy	60,000	Commutators, slip rings, high conductivity
Steb Metal	Ag on Cu		Silver rolled into copper
Combarloy	Ag and Cu alloy		High conductivity commutator bars
Silver Alloys			
Elkonite	Ag – WC or 40 Ag, 60 Mo		Contactors, high conductivity, easily machined Brinell hardness No. 110–150
Elkonium No. 1	Ag alloy		Substitute for fine silver contacts
Fasaloy	Ag, Cu, Co		
Gibsaloy Grade A	95 – 50 Ag, 5 – 50 Ni		Sintered powder electrical contacts
Grade C	99 – 93 Ag, 1 – 7 graphite		
Grade NM	1 – 35 Ni, 1 – 30 Mo, rest is Ag		Contacts for high current densities
Grade NW	1 – 35 Ni, 1 – 30 W, rest is Ag		Contacts for high current densities
Fastell	Silver alloy		Electrical contacts, various grades are made by alloying Ag with various hardening metals
Mallory D-50	Silver alloys	30,000	
Tungsten and Other Alloys			
Elkonite (10-W-3)	77 W, 23 Cu	55,000	Sintered alloy, does not respond to heat treatment, Brinell hardness No. 225
Mallory HA & HB Metal	W-alloy		
Wilcoloy	WC		Telegraph relays (tungsten carbide)
Milwaloy 18	Fe, Ni, Mn		Nonmagnetic for use in circuit breakers
Aeralloy	Pt alloy		
Elkonium No. 13	Pd alloy		Brinell hardness No. 240
Paliney	Pd, Pt, Ag, Cu, Ni or Au	170,000	Nonmagnetic contacts, pivots, bearings, springs, grade No. 6 (Brinell H. No. 240) can be heat treated, grade No. 7 (Brinell, hardness No. 280) is corrosion and wear resistant
No. 712 Alloy	29 Os, 40 – 50 Ir, rest is Pt		
Electrical Gold Alloy	70 Au, 25 Ag, 5 Ni		

ELECTRONIC TUBE METALS

Name	Composition, Approximate Percent	Typical Applications and Remarks
Aluminum		Commercial Al is about 99.94 percent pure, work hardens, melts at 1,220 F
Baral	Up to 50 Ba, rest is Al	Getters, stable in air
Calloy Strontium-Aluminum	Up to 50 Sr, rest is Al	Getters, stable in air
Barium	100 Ba	Malleable and lustrous
Beryllium	100 Be	Windows for x-ray tubes, light metal, coef. of exp. of cast iron
Misch Metal	50 Ce, 45 La, 5 others	Getters
Columbium	100 Cb	Lowest work function of pure refractory metals, melts at 1,950 C
Copper		Pure copper melts at 1,981 F; in various forms copper is used for components of electronic tubes requiring high conductivity, but because of its softness it is frequently coated or plated on a structural metal
Electrolytic Copper	99.9 Cu	
Lake Copper	99.9 Cu	
Arsenical Lake Copper	99.4 Cu, 0.3 As, 0.2 O_2	
Casting Copper	98.5 – 99.8 Cu	
Deoxidized Copper	99.95 Cu, Ag, 0.01 – 0.05 P	
Gallium	100 Ga	Photoelectric cells and tubes, melts at 29.9 C, coef. of exp. 0.000018
Gold	100 Au	Plated on structural parts to provide high conductivity, melts at 1,945 F
Graphite (Carbon)	99.997 C	Anodes in high-power vacuum tubes
Iron		Pure iron is not used commercially, but it is frequently an alloying metal, melts at 2,786 F
Radiohm	12 – 13 Cr, 4 – 5 Al, balance is Fe	Tube parts, resistant to heat to 1,000 C
D-H No. 42 Alloy	41.5 – 43 Ni, rest Fe	Glass-metal seals, coef. of exp. of glasses, max operating temp. 400 C
Platinite	54 – 58 Fe, 46 – 42 Ni, 0.15 C	To replace Pt in electronic tubes, heat resistant, coef. of exp. of glasses, glass-metal seals
Dilver	54 – 58 Fe, 42 – 46 Ni	Heating elements, properties similar to Platinite
Dumet	54 Fe, 46 Ni, plated with Cu	Resistance alloy for sealing in glass bulbs, Platinite with an oxidized Cu plated coating
Fernico	54 Fe, 28 Ni, 18 Co	Metal-glass joints, same coef. of exp. as glasses
Kovar	30 Ni, 15 Co, 0.2 Mn, balance is Fe	Low expansion alloy for hard glass-metal seals, mean expansivity (25 – 400 C) is 0.0000045
Fernichrome	37 Fe, 30 Ni, 25 Co, 8 Cr	Metal seals to soft glass, substitute for Dumet
Nilstain 416	23 – 30 Cr, 0.35 C (max), balance is Fe	Glass sealing wire, heat resistant
Molymet	45 Fe, 45 Ni, 10 Mo	Grid wire
Magnesium		Commercial Mg is 99.9 percent pure, constitutent of light alloys, cannot be cold forged, getter material for O_2
Barmay	35 Ba, balance is Mg	Getters
Revere Magnesium M	Mn and Mg	Tube parts and resistances
Nickel		Pure nickel has a high temp. coef. of resis., melts at 2,646 F (Show us the tube that does not have some nickel in it!)
Hoskins 651	100 Ni	
A Nickel	99 Ni & Co (min), 0.25 Cu, 0.3 Fe, 0.35 Mn, 0.2 C, 0.2 Si, 0.008 S (max)	Constructional parts of electronic tubes, base pins, support wires and rods, grid side rods, getter tabs, shields, thyratron grids
220 Nickel	99 Ni & Co (min), 0.2 Cu. 0.2 Fe, 0.2 Mn, 0.15 C, 0.01 – 0.05 Si, 0.008 S (max)	Hot cathodes (225 Nickel, having higher Si content, can be used where liberation of appreciable Ba is not objectionable), this grade is used if libearation of Ba is to be minimized
330 Nickel	99 Ni & Co (min), 0.15 Cu, 0.2 Fe, 0.2 Mn, 0.15 C, 0.1 Si, 0.008 S (max)	Anodes, cold cathodes, and structural parts
Alloy No. 484	98 Ni, 2 Mn	Sparking electrodes
Tantalum-Nickel	Ni plus Ta	Less expensive substitute for tantalum
Gridnic A-F		Grid wires and other wire parts
Mangrid D, E	4.5 or 20 Mn, balance is Ni	Vacuum tube grid wire, magnetic
Filnic, H-K	Ni, Co, Ti, Fe, Si	Resistance metal for filaments and heaters
D-H No. 52 Alloy	51 – 52 Ni, balance is Fe	Glass-metal seals and grid wires, max. operating temp. 500 C
Sylvaloy	97 Ni, 3 Si	Vacuum-tube filaments
Tensite	98 Ni, 2 Al	Vacuum-tube filaments
Konel	73.07 Ni, 17, 16 Co, 8.8 Ti, 0.55 Si, 0.26 Al	Filaments, substitute for platinum, heat and corrosion resistant, hot short above 1,250 C
Palladium	100 Pd	Malleable, ductile, hard, melts at 2,822 F
Platinum	100 Pt	Melts at 1,773 C (3,191 F)
Silver	100 Au	Melts at 1,761 F, used for high-conductive coating
Tantalum	100 Ta	Electrodes, melts at 2,996 C, corrosion resistant, nonmagnetic, secondary emission comparable to W, work function is lower, used for grids in tubes having thoriated tungsten filaments, electron emission at 2,100 K is comparable to that from tungsten at 2,500 K
Tungsten	100 W	Filaments and heaters, melts at high temperature of 6,152 F (3,370 C), nonmagnetic, oxidizes when heated in air, used for electron emitters, targets in x-ray tubes, arcing contacts because of its low vapor pressure
Tungsten Filaments	0.5 – 0.75 ThO_2 balance is W	Common grade of tungsten used for filaments
Zirconium	100 Zr	Substitute for Pt, melts at 3,090 F

PLASTICS . . . . molding and casting

Molding or Casting Material	Type	Power Factor			Dielectric Constant			Diel. Strength *v/mil*	Volume Resistivity *meg-cm*
		60 cps	1 kc	1 mc	60 cps	1 kc	1 mc		
Allyl Resin, Cast	TS	0.019	0.01–0.018	0.06	3.45	3.25–3.8	3.6	570–1,275	$> 10^8$
Aniline Formaldehyde Resin No Filler	TP	0.002	0.004	0.006–0.008	3.7–3.8	3.7	3.5–3.6	600–650	10^{10}–10^{11}
Casein	—	—	—	0.052	—	—	6.1–6.8	400–700	—
Cellulose Acetate, Molding	TP	0.06	0.06	0.1	7.5	7.0	7.0	250	10^4
Cellulose Acetate Butyrate	TP	0.04	—	0.04	6.4	—	6.2	250	10^4
Cellulose Nitrate (Nitrocellulose; Pyroxylin)	TP	0.06–0.15	—	0.07–0.1	6.7–7.3	—	6.2	300–600	10^4
Cellulose Propionate (Cellulose Acetate Propionate)	TP	0.004–0.007	0.07 – 0.013	0.015–0.032	3.0–3.5	3.1–3.5	3.0–3.5	370–410	10^6–10^8
Cold-Molded Compound, Inorganic Refractory Ceramic)	TS	—	—	—	—	—	—	—	—
Cold-Molded Compound, Organic (Nonrefractory)	TS	0.2	—	0.07	15	—	6	85	1.3×10^6
Ethyl Cellulose	TP	0.01–0.02	0.02–0.03	0.03–0.04	3.8–4.0	3.7–3.8	3.5–3.7	250–350	10^4
Melamine Formaldehyde Asbestos Filler	TS	0.08	0.05	0.03	8.0	7.3	6.7	300	10^5
Melamine Formaldehyde Cellulose Filled	TS	0.08	0.05	0.06	9.5	9.0	8.2	300	10^5
Methyl Methacrylate (Acrylic)	TP	0.06–0.07	0.05–0.06	0.03–0.04	4.0	4.0	3.0–3.5	400	10^6
Nylon (Polyamide)	TP	0.05	0.05	0.07	5.0	5.0	4.0	350	10^5
Phenol Formaldehyde No Filler (PF_1)	TS	0.10	0.08	0.03	6.5	6.0	5.0	300	10^5
Phenol Formaldehyde Wood Flour Filler (PF_2)	TS	0.12	0.06	0.06	7.0	6.0	5.5	300	10^5
Phenol Formaldehyde Cellulose Filler (PF_3)	TS	0.20	0.08	0.06	9.0	8.0	6.0	300	10^5
Phenol Formaldehyde Cellulose Filler (PF_4)	TS	0.25	0.10	0.06	9.0	8.0	6.0	200	10^5
Phenol Formaldehyde Cellulose Filler (PF_5)	TS	0.25	0.10	0.06	10.0	8.0	6.0	200	10^5
Phenol Formaldehyde Cellulose Filler (PF_6)	TS	0.25	0.10	0.06	10.0	8.0	6.0	200	10^5
Phenol Formaldehyde Mineral Filler (PF_7)	TS	0.05	0.03	0.02	6.0	5.5	5.0	350	10^6
Phenol Formaldehyde Mineral Filler (PF_8)	TS	0.025	0.02	0.01	6.0	5.5	5.0	350	10^6
Phenol Formaldehyde Mineral Filler (PF_9)	TS	0.42	0.40	0.20	50	30	8	200	10^3
Phenol Formaldehyde Mineral Filler (PF_{10})	TS	0.35	0.25	0.10	15	12	7	300	10^5
Phenol Formaldehyde Sisal Felt Filler	TS	0.1–0.3	—	0.3–0.5	5–10	—	3–5	250–400	10^5–10^6
Phenol Formaldehyde, Cast No Filler	TS	0.025–0.5	0.01–0.3	0.01–0.1	6.5–30	5.5–18	5–11	75–450	10^4–10^6
Phenol Formaldehyde, Cast Mineral Filler	TS	—	0.1–0.3	0.07–0.2	—	14–30	9–15	100–250	10^3–10^6

compounds, laminates, and synthetic and natural rubbers

Heat Distort. Temp. °F	Max. Service Temp. °F	Impact Strength Izod ft lb/in.	Tensile Strength lb/sq in.	Hardness Rockwell	Specific Gravity	Linear Expans. in./in./°C×10⁻⁵	Typical Trade Names and Remarks
140–200	212–225	0.3–0.4	5,000–6,000	M95–M115	1.32–1.40	5.5–10	Allymer; Kriston. Used as or in molding, casting and coating compositions. Transparent but readily colored. Withstands heat.
210–245	180–190	0.32	8,500–10,000	M115–M120	1.22–1.25	5–6	Cibanite; Dilectene. High dielectric strength and weather resistance. Used for radio insulators.
300	300–325	1.0	10,000	M70–M100	1.35	4.1–6.8	Ameroid; Galorn. Cheap and easy to mold. Hardened by formaldehyde or similar agent, and seasoned by drying.
100–160	120–210	0.5–3.0	2,000–6,000	R38–R114	1.32–1.34	16	Bakelite; Chemaco; Fibestos; Hercules flake; Kodapak; Lumarith; Nixon; Plastacele; Tenite; Vuepak. Light, tough; many colors.
100–150	120–130	0.6–3.1	2,000–5,000	M15–M56	1.18–1.23	17	Tenite II; Hercose. Also called acetobutyrate. Better moisture resistance and dimensional stability than cellulose acetate.
120–165	140	2–8	3,000–10,000	R90–R120	1.35–1.4	9–16	Celluloid; Hercules flake; Nitron; Nixonoid; Nixon; Pyralin. Highly inflammable; excellent molding qualities.
120–150	140–220	0.8–11.4	2,800–6,000	R63–R104	1.17–1.22	12–19	Forticel; Tenite III. Used for radio housings and cabinets. Tough; high impact strength; surface lustre; stable.
—	700–1,300	0.4	—	M35–M65	1.8–1.9	0.8	Aico; Hemit; Textolite. Ceramic type, thermosetting after baking Resists heat and arcing. Gray, black only.
—	400–500	0.4	—	M35 M65	1.87–2.15	1.4	Aico; Amerine; Garit; Gummon; Textolite; Thermoplax. Becomes TS during baking. Resists heat, arcing. Low cost. Dark colors.
110–140	150	2.5–5.0	1,000–6,000	R78–R100	1.09–1.19	15	Celcon; Chemaco; Ethocel; Ethofoil; Hercules flake; Lumarith; Nixon. Tough, durable, resistant to sun and chemicals.
270	210	0.2	5,000	M109	2.2	4.5	Melmac; Plaskon; Resimene. Resistant to heat, arcing, surface tracking, water, chemicals. For insulation, radio cabinets. Properties vary with filler used; cellulose filler gives 125-sec arc resistance for uses like connector inserts.
300	260	0.2	6,000	M112–M122	1.55	2–4.5	
130–180	—	0.1–0.2	5,000–9,000	M105	1.2	9	Lucite; Plexiglas. Used to pipe light; for solid and liquid-filled lenses; dials; escutcheons. Easily colored. Softens in hot water.
160	—	0.6	9,000	M80	1.15	10.3	Marketed under generic name nylon. Widely used for injection molding; tough, strong; can be boiled; can be molded in thin sections.
230	250	0.3	6,000	M124	1.30	—	Bakelite; Catapak; Co-Ro-Lite; Drackett; Durez; Durite; Heresite; Indur; Insurok; Makalot; Micarta; Neillite; P-C-I; Resinox; Textolite. Values given apply also to phenol-furfural and furfural-aldehyde-phenol molding materials, used during World War II when furfuraldehyde was in greater supply than formaldehyde.
260	300	0.2	6,000	M115	1.45	3.5	
250	300	0.3	6,000	M110	1.42	3.3	Phenolics are available in many different types, produced by varying conditions of initial condensation reaction and by compounding with various filler materials, so they can be used for molding or casting, coatings, laminating materials, and adhesives. Phenolics are relatively inexpensive; widely used for radio cabinets, electrical appliance housings, knobs, electrical plugs, telephone handsets, component parts of electrical devices, switch plates, insulation. Colors are limited and not translucent or transparent. Not recommended where resistance to alkalies is needed.
250	300	0.8	5,000	M110	1.45	2.93	
250	250	1.7	6,000	M110	1.45	—	
250	250	4.0	6,000	M110	1.45	2.0	
250	300	0.3	5,000	M100	2.0	—	Mineral filler gives low-loss insulating material for high-frequency applications; mica and asbestos are both used for this purpose. Mica-filled molded products are generally low in mechanical strength and difficult to machine, but have a low coefficient of thermal expansion and low shrinkage, along with heat resistance such that they withstand up to 450 deg F intermittently.
250	250	0.3	5,000	M100	2.0	1.9	
250	100	0.7	1,000	M100	2.0	2.0	
280	260	0.2	4,000	M95	2.0	2.12	Designations in parentheses are from the SPI Handbook; subscript designations 4, 5, and 6 are moderate, medium, and high impact strength respectively; 8 is superior to 7 in electrical high-frequency low-loss properties; 9 is general-purpose and 10 is heat-resistant, mineral-filled material. Sisal felt filler gives high tensile and impact strength but has high linear thermal expansion.
320	250	3–16	7,000–12,000	—	0.7–1.35	7–20	
95–165	160	0.25–0.6	2,000–9,000	M20–M110	1.26–1.33	5–15	Bakelite; Catalin; Gemstone; Marblette; Prystal. Available in unlimited color range including mottling and two-tone. Used for radio and clock cabinets, gay ornamentation on juke boxes, gage and meter windows, and photoelastic stress analysis.
150–175	160	0.35–0.5	4,000–9,000	M95–M120	1.7	7.5	

Plastic molding and casting compounds (continued)

Molding or Casting Material	Type	Power Factor			Dielectric Constant			Diel. Strength *v/mil*	Volume Resistivity *meg-cm*
		60 cps	1 kc	1 mc	60 cps	1 kc	1 mc		
Polydichlorostyrene	TP	0.0003–0.0008	0.0002	0.0002	2.64–2.66	2.62	2.62	370	—
Polyethylene	TP	0.0002–0.0005	0.0002–0.0005	0.0002–0.0005	2.25–2.3	2.25–2.3	2.25–2.3	460–470	10^{10}–10^{11}
Polystyrene	TP	0.0003–0.0005	0.0003–0.0005	0.0005–0.001	2.6–2.75	2.6–2.75	2.6–2.75	450–500	10^{9}–10^{11}
Polystyrene with Chlorinated Diphenyls	TP	0.002	0.003	0.001	2.8	2.8	2.8	400	10^{13}
Polytetrafluoroethylene	TP	<0.0002	<0.0002	<0.0002	2.0	2.0	2.0	500	$>10^{16}$
Polyvinyl Butyral Resin Flexible, Filled	TP	0.057	0.040	0.045	6.5	6.1	5.0	350	2×10^{5}
Polyvinyl Butyral Resin Flexible, No Filler	TP	0.115	0.057	0.060	5.60	5.10	3.92	175–375	5×10^{4}–10×10^{4}
Polyvinyl Butyral Resin Rigid	TP	0.007	0.0075	0.0065	3.61	3.58	3.33	400	$>10^{8}$
Polyvinyl Butyral Resin Thermosetting	TS	—	0.01–0.1	0.02–0.1	—	4–13	4–10	175–375	—
Polyvinyl Carbazole	TP	0.0005–0.001	0.0004–0.001	0.0004–0.001	3.0	3.0	3.0	750–1,000	10^{9}–10^{10}
Polyvinyl Chloride Resin Plasticized	TP	0.10–0.15	0.09–0.16	0.09–0.10	5.8–6.4	4.2–5.5	3.3–3.5	325–425	1×10^{8}–50×10^{8}
Polyvinylidene Chloride (Vinylidene Chloride)	TP	0.042	0.075	0.065	6.0	5.0	4.0	350	10^{8}
Polyvinyl Chloride Acetate Rigid	TP	0.007–0.01	0.011–0.013	0.018–0.019	3.2–3.3	3.1–3.2	3.0–3.1	400–425	10^{8}
Polyvinyl Chloride Acetate Flexible, Filled	TP	0.055	0.063	—	8.1–8.3	6.9–8.4	—	340–400	2×10^{7}
Polyvinyl Chloride Acetate Flexible, No Filler	TP	0.084	0.123	0.100	8.1–8.3	6.9–8.4	4.2	150–300	5×10^{6}
Polyvinyl Formal	TP	0.007	0.01	0.02	3.6	3.3	3.0	300–600	—
Shellac Compound	TP	0.004–0.04	0.05	—	3–4	4–5	—	200–600	1.8×10^{3}
Styrene Copolymer Cross Linked	TS	0.0003	0.00015	0.00025	2.4–3.0	2.4–3.0	2.4–3.0	325–550	$>5 \times 10^{10}$
Styrene Elastomer	TP	0.0012	0.0005	0.001	2.4	2.5	2.5	600	10^{9}–10^{10}
Styrene Resin, Modified	—	—	—	0.0003–0.0006	—	—	2.7–2.9	—	10^{9}
Urea Formaldehyde Alpha Cellulose Filler	TS	0.10	0.055–0.06	0.04	9.5	9.0	7.5	300	10^{6}

NOTES

In general, single values have been taken from the Classification of Plastics chart published in 1948 by the Society of the Plastics Industry. These values constitute a conservative approach providing adequate factors of safety in design.

Properties have in most cases been determined by ASTM (American Society for Testing Materials) test methods, at room temperature under standard test conditions. Values will generally be appreciably different above or below room temperature, hence this variation must be carefully considered if the application involves wide temperature ranges.

For materials not included in the SPI Classification of Plastics, values were taken from manufacturers' data and other sources. These values differ widely for identical plastics in many cases because small variations in manufacturing methods, in composition and in molding conditions cause wide variations in certain properties. The ranges shown therefore constitute the limits of values given in the various sources.

In all cases, manufacturers should always be consulted before making a definite choice of material. This tabulation is intended as a guide to relative properties of the various commercially available plastics.

Type Designations: TP—thermoplastic; can be repeatedly softened by heat and reformed; TS—thermosetting; becomes infusible when heated during or after molding, and cannot be appreciably softened when heat is reapplied.

Power Factor: Determined by ASTM D 150-42T Test Method. Maximum values are given.

Dielectric Constant: Determined by ASTM D 150-42T Test Method. Maximum values are given. For electronic applications it is desirable that values be low for dielectric constant and power factor.

Dielectric Strength: Determined by Short Time method in ASTM D 149-44T Test Method for ⅛" thickness. Minimum values are given expressed in volts per mil of thickness. For high-voltage electronic applications, high values are desirable here.

Volume Resistivity: Determined by ASTM D 257-38, which involves measuring the resistance in megohms between two electrodes covering opposite faces of a centimeter cube of the material. Minimum values are given.

Heat Distortion Temperature: Determined by ASTM D 648-41T at 264 pounds per square inch fiber stress, and represents temperature at which a centrally loaded simple beam will deflect 0.010 inch when subjected to temperature rise in standard time-temperature-time increments. Values for polyethylene and polytetrafluoroethylene were obtained at 66 psi since these materials are generally suitable only for low-stress applications.

Maximum Continuous Service Temperature:

Heat Distort. Temp. °F	Max. Service Temp. °F	Impact Strength Izod ft lb/in.	Tensile Strength lb/sq in.	Hardness Rockwell	Specific Gravity	Linear Expans. in./in./°C×10⁻⁵	Typical Trade Names and Remarks
230–250	212–230	0.3–0.5	4,500–8,500	M90–M103	1.38–1.4	—	Mathieson DCS. Modification of polystyrene having higher heat distortion point, lower water absorption. Cost is high.
122	140–200	>3	1,700–1,900	R35–R40	0.92	18–24.8	Bakelite; Polythene. Excellent electrical properties, nearly constant up to 3,000 mc. No known solvents at room temp. Low-priced. It floats.
170	150	0.3	5,000	M80	1.07	8	Bakelite; Chemaco; Koppers; Loalin; Lustron; Plexene; Styron; Textolite. Good high-frequency insulator up to 3,000 mc.
180	—	0.2	3,000	—	1.4	—	Styramic. Higher heat distortion value than polystyrene and comparable strength and cost, and almost as good electrically.
266	>400	4.0	2,000–4,500	—	2.1–2.3	9	Teflon. Used for insulators and wire insulation. Usable from −100 to 480°F. Losses constant up to 3,000 mc. Noninflammable.
—	—	—	500–3,500	—	1.1–1.5	—	Butacite. Tough; resistant to light, heat, and water. Retains flexibility and toughness over wide temperature range. Impact strength varies with type and amount of plasticizer. One modified type is thermosetting. Used as safety glass interlayer, for fabric impregnation and coating, and as plywood adhesive. Slow burning rate. Acids and alkalies have slight effect. Unlimited colors, from transparent to opaque. Also called vinyl butyral. Available in sheets and flakes.
—	—	—	500–3,500	—	1.05	—	
115–140	115	0.8–1.2	4,000–8,500	—	1.07–1.2	8–22	
—	100–140	—	500–3,500	—	1.1–1.5	36	
210–320	—	0.5–1.0	4,000–6,000	—	1.2	5–8	Polectron. High heat distortion point. Retains excellent electrical characteristics up to 3,000 mc even at high temp.
—	150–175	—	1,000–9,000	—	1.2–1.6	—	Chemaco; Geon. Excellent chemical resistance, low water absorption. For extruded wire covering and tubing.
150	150	0.5	4,000	M50	1.75	19	Saran. High tensile strength. Practically inert chemically. Excellent molding qualities.
120–130	130	0.2–0.3	4,000–7,000	—	1.35–1.4	7	Chemaco; Tygon; Vinylite. Varying composition and degree of polymerization gives wide range of properties for extrusion, molding, casting and surface coating. High gloss. Used for insulation, radio dials and windows, transcription records, unbreakable home records, grommets, and name plates. Unlimited range of colors. Elastomeric (flexible like rubber).
—	125	—	850	—	1.7	—	
—	150	—	1,000–9,000	—	1.2–1.6	0.3–0.5	
160–170	—	0.5–1.0	9,000–12,000	M80	1.2–1.3	7.7	Formvar. Vinyl-base resin used for extrusions, castings and in molding compounds. For wire insulation, coatings.
—	150–190	2.6–2.9	900–2,000	—	1.1–2.7	—	Complac; Compo-Site. Animal resin used in making molding compounds used for phonograph records, insulators.
217–235	—	0.25–0.35	7,000–10,000	M68–M95	1.04	5.9–9	Plexene; Textolite. High heat resistance, low power factor, good chemical and weather resistance. For r-f coil forms.
140–150	140–200	1.5–2.0	900–1,200	—	0.95–0.97	18–23	Styraloy; Styron. Low specific gravity; floats. Can be used at up to 435°F. Rubberlike, flexible; for cable sheathing.
117–126	—	0.28	4,800	—	1.05	—	Marbon. Used principally with synthetic rubbers for wire and cable insulation. Light amber in color. Low-priced.
270	170	0.2	6,000	M110	1.55	3.0	Beetle; Plaskon; Rhonite; Synvarol; Uformite; Urac. Electrically nontracking. For radio cabinets, insulators.

Maximum values recommended for molded parts under no stress for long and short time. Some are higher and some lower than corresponding heat-distortion temperatures, hence both columns should be closely studied when considering applications subject to heat. These temperatures do not apply to parts immersed in water, chemical solutions, or solvents.

Impact Strength Izod: Minimum value in foot-pounds per inch notch, determined by ASTM D 256–43T, which is one of the most widely used tests for plastics. It represents energy required to break a bar of plastic held in cantilever fashion.

Tensile Strength: Amount of load in pounds per square inch of cross-section, required to pull a test specimen apart. Used principally as guide in applications primarily structural, and is valuable identification test for the soft thermoplastics where impact test is not practical.

Hardness: Minimum value obtained by Rockwell test. The M scale involves a ¼-inch diameter steel ball with 100-kilogram major load, while the R scale uses a ½-inch ball and 60-kilogram load. The higher the value, the greater is the hardness.

Specific Gravity: Maximum value obtained by ASTM D 792–44T.

Coefficient of Thermal Expansion, Linear: Maximum value, giving inches expansion per inch of length per degree Centigrade change in temperature (multiply values given by 10^{-5}). Important when plastics are used in conjunction with metal inserts or metal components in final assembly.

Trade Names: Representative examples are given, and in most cases there are many others. Trade names are identified as to manufacturer elsewhere in this directory (in Trade Name Index)

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Properties of Laminated Thermosetting Plastic Products

Laminating Resin and Base	NEMA Grade	Power Factor 1 mc	Dielec. Constant 1 mc	Dielectric Strength		Impact Strength Izod	Flexural Strength *psi*	Compressive Strength *psi*	Tensile Strength *psi*
				Short Time	Step by Step				
Lignin Plastic	———	0.041	6.0	200	170	0.7	12,500	27,500	7,500
Melamine Formaldehyde, Asbestos Paper	———	0.18	9.0	125	70	1.2	21,000	37,000	9,000
Malamine Formaldehyde, Cellulose Paper	———	0.4	8.0	550	325	0.9	28,000	40,000	17,000
Melamine Formaldehyde, Cotton Fabric	———	0.4	7.0	350	300	1.4	20,000	40,000	15,000
Melamine Formaldehyde, Glass Fabric	G-5	0.01	7.2	500	360	30	39,000	65,000	45,000
Phenol Formaldehyde, Asbestos Fabric	AA	0.44	6.8	50	30	3.5	20,000	38,000	10,000
Phenol Formaldehyde, Asbestos Felt	———	——	——	70	50	4	34,000	35,000	23,000
Phenol Formaldehyde, Asbestos Paper	A	0.115	5.2	160	95	1.8	16,000	36,000	8,000
Phenol Formaldehyde, Cellulose Paper	X	0.06	6.0	500	360	1.3	23,000	35,000	14,000
Phenol Formaldehyde, Cellulose Paper	P	0.06	6.0	500	360	1.1	15,000	22,000	8,000
Phenol Formaldehyde, Cellulose Paper	XX	0.04	5.0	500	360	1.0	16,000	34,000	9,000
Phenol Formaldehyde, Cellulose Paper	XXP	0.04	5.0	500	360	3.0	16,000	25,000	8,000
Phenol Formaldehyde, Cellulose Paper	XXX	0.032	4.8	470	320	0.8	15,000	32,000	7,000
Phenol Formaldehyde, Cellulose Paper	XXXP	0.027	4.5	470	320	0.5	15,000	25,000	7,000
Phenol Formaldehyde, Cotton Fabric	C	0.1	7.0	150	90	3.2	20,000	38,000	9,500
Phenol Formaldehyde, Cotton Fabric	CE	0.055	5.5	360	220	2.3	17,000	36,000	8,000
Phenol Formaldehyde, Cotton Fabric	L	0.10	7.0	150	90	2.5	20,000	35,000	9,000
Phenol Formaldehyde, Cloth	LE	0.045	5.0	360	220	1.8	19,000	37,000	8,500
Phenol Formaldehyde, Glass Fabric	G-1	0.02	4.5	550	400	4.0	24,000	45,000	25,000
Phenol Formaldehyde, Glass Fabric	G-3	——	——	500	395	10	———	———	———
Phenol Formaldehyde, Glass Fabric	———	0.028	5.0	300	200	8.5	22,000	———	14,800
Phenol Formaldehyde, Nylon Fabric	———	0.03	3.5	475	375	4.5	21,500	31,000	9,000
Phenol Formaldehyde, Wood	———	0.05	5	350	——	6	32,000	16,000	24,000
Silicone, Asbestos Fabric	———	——	——	100	75	7.5	14,000	45,000	———
Silicone, Glass Fabric	———	0.0015	——	300	250	10	14,000	35,000	13,000
Vulcanized Fiber	———	——	4.7	200	——	4	16,000	26,000	8,500

NOTES

The materials listed above are in most cases available also as tubing and as rods either machined from sheets or molded and then ground to size.

NEMA Grade: Established by National Electrical Manufacturers Association (Pub. No. 46–118—Standards for Laminated Thermosetting Products, Aug. 1946) for laminates using phenolic resin binders (except G-5 which uses a melamine binder).

Average values are given throughout; actual

Properties of Synthetic and Natural Rubbers

Material	Power Factor at 1,000 cps	Dielectric Constant at 1,000 cps	Dielectric Strength Short-time *v per mil*	Volume Resistivity at 25° C *ohm-cm*	Maximum Service Temperature °F	Tensile Strength *lb per sq in.*
Butadiene-Acrylonitrile Copolymer	0.1	14	500–750	10^{2}–10^{10}	250–300	3,200–4,000
Butadiene Styrene Copolymer	0.003–0.005	2.9	750	10^{15}–5×10^{15}	212–300	2,200–4,000
Polychloroprene	0.03	7.5	———	———	300	4,000–4,700
Cyclorubber	0.0008–0.0018	2.6–2.7	620	2.5×10^{11}	158–194	4,800
Isoprene-Isobutylene Copolymer	0.0004–0.0007	2.1–2.3	500–700	10^{14}–10^{18}	300	2,800
Organic Polysulfide	———	———	———	———	200–300	790–2,000
Polyisobutylene (Polybutene)	0.0002–0.0005	2.29	400–750	10^{13}–10^{16}	200–300	300–1,500
Polyvinyl Alcohol	———	———	———	10^{2}–10^{8}	250–275	2,000–6,000
Rubber, Chlorinated	0.006	3	2,300	2.5×10^{13}	140	2,700–5,000
Rubber, Hard, Mineral Filler	0.006	4.8	600	2×10^{13}	250	4,000
Rubber, Hard, Without Filler	0.004	3.0	470	2×10^{15}	180	9,000
Rubber, Modified Isomerized	0.002	2.68	620	$5–7 \times 10^{16}$	165–220	4,300
Silicone Rubber	0.002–0.006	3–10	500–1,100	10^{11}–10^{14}	520	400–700

Hardness Rockwell	Specific Gravity	Linear Expansion	Water Absorption %	Typical Trade Names and Remarks
M90	1.4	2.3	0.8	Benelex. Natural resin used by itself or with phenolics as laminates and in molding compounds. Good up to 175F.
M115	1.8	——	3.0	Dilecto. For arc and flame resistant applications. For temp. up to 245F. Gray color. All melamine laminates are TS.
M125	1.5	——	0.5	Dilecto; Panelyte. Unlimited colors, tough, strong, low water absorption, good chemical resistance. Good up to 260F.
M115	1.5	——	0.8	Formica. Good chemical resistance, tough, excellent machining qualities. For table tops, panel boards, etc.
M120	1.9	——	1.1	Formica; Lamicoid; Micarta; Phenolite; Taylor; Textolite. Strong, flame-resistant, for combat ship insulation.
M100	1.7	1.8	0.85	Phenol Fibre; Dilecto. Good resistance to heat and flame because of high inorganic content; fabric is tougher, stronger, and more resistant than paper grade. For low-voltage applications only. All phenol formaldehyde laminates are thermosetting. Low water absorption and minimum dimensional change when exposed to moisture.
M115	1.6	——	0.85	
M100	1.7	1.0	0.85	
M100	1.4	2.0	2.3	Consoweld; Farlite Compreg; Formica; Inderon; Insurok; Lamitex; Panelyte; Pregwood; Phenol Fibre; Spauldite; Synthane. In general, paper-base grades have high dielectric and mechanical strength, low moisture absorption, and are suitable for hot-punching. One major use is for insulation in radio and electronic equipment. Grade X is for mechanical applications where electrical properties are secondary; P is primarily intended for punching; XX is suitable for usual electrical applications, while XXP is similar but better suited for hot-punching; XXX is suitable for r-f work and high-humidity jobs, while XXXP is similar but with lower dielectric losses and is better for hot-punching. Unlimited colors.
M101	1.37	1.4	1.9	
M102	1.35	1.7	0.95	
M105	1.35	1.9	0.95	
M109	1.35	1.7	0.70	
M114	1.30	1.8	0.70	
M100	1.35	2.0	1.70	Dilecto; Formica; Lamicoid; Micarta; Panelyte; Phenol Fibre; Phenolite; Spauldite; Synthane; Textolite. Tough, good machining, opaque, limited range of colors; sunlight lowers surface resistance; very low burning rate. NEMA grade C is tough and strong for gears, and has high impact strength; CE is tougher; L is from finer cotton fabric, not so tough, while LE is similar but tougher, with good moisture resistance. All four grades are unsuited for electrical applications except at low voltages. Certain other cloth-base grades can be post-formed.
M104	1.35	1.8	1.2	
M100	1.36	1.4	1.4	
M105	1.34	1.8	0.9	
M109	1.6	1.5	1.5	Conolon; Formica. Used primarily for resistance to heat, chemicals, and fatigue. High strength and high modulus of elasticity. Some types are good up to 400F. All are general-purpose heat-resisting grades, G-1 being from staple-fiber-type glass cloth and the others continuous-filament-type glass cloth. Unlimited colors.
M119	1.7	1.8	2.0	
——	1.67	——	2.2	
M110	1.15	——	0.2	Dilecto. Excellent electrical insulating properties, resistance to fungi and strength for radar and electronic insulation.
M100	1.3	0.6	7.0	Pregwood. Low burning rate. Limited range of colors. Good machining. Used for making propellers, insulation, etc.
——	1.75	——	1.3	Formica; Textolite. Withstands temperatures over 480F, with unusual properties that often justify its high cost. Limited range of opaque colors. Not affected by sunlight. Does not burn. Good machining qualities.
M100	1.7	——	0.6	
R80	1.3	——	40	Diamond Fibre; National; Taylor; Vulcoid; Wilmington Fibre. Not a true laminate; values shown here for comparison.

values vary widely with manufacturing methods and chemical compositions, hence specific values should be obtained from manufacturers before designing for a particular application.

Standard ASTM test methods were in general used in obtaining the average values given. Dielectric strength values are in volts per mil for ⅛-inch thickness. Impact strength is in ft-lb per inch of notch as described for molded plastics. Linear expansion is in inches per inch per degree C × 10^{-6}. Water absorption is for 24-hour immersion of ⅛-inch thickness.

Elongation at break %	Specific Gravity	Swelling in Gasoline (ASTM Test) % by volume	Typical Trade Names and Remarks (All values given vary widely with formulation and compounding of material.)
100–800	0.96–1.00	−5 to +15	Buna-N; Chemigum; Hycar; Perbunan; Butaprene. Excellent abrasion resistance.
100–700	0.98	+75 to +200	Buna-S; Chemigum; GR-S; Hycar. Somewhat more difficult to machine than hard rubber.
300–1,100	1.15–1.24	+10 to +45	GR-M; GR-M10; Neoprene. Also called chlorobutadiene polymer. Resistant to sunlight.
under 10	0.97	——	Marbon B. First two values are for 1 mc. Used for wire and cable insulation.
300–1,000	0.91	+150 to +400	Butyl Rubber; GR-I. Highly resistant to sunlight and aging. Values are for unvulcanized.
300–700	1.27–1.6	0 to +2.5	Thiokol. Good chemical resistance; fair mechanical qualities. For tank linings, oil hose.
600–1,500	0.9–0.92	Soluble	Vistanex. Usually compounded with other materials for wire insulation, capacitor dielectrics.
300–600	1.26	−0.3 to +0.7	Compar; Resistoflex. Impervious to water-insoluble solvents; attacked by acids.
0.5–3.8	1.64	Insoluble	Parlon. Resistant to acids and alkalies. Darkens in sunlight. Won't burn.
1.25	1.82	Softens	Ace; Luzerne; Rubtex. Resistant to alkalies. Discolors in sunlight. Medium burning rate. Attacked by strong oxidizing acids. Widely used for panels, terminal strips, insulation.
7.5	1.14	Softens	
——	0.97–1.06	Softens	Marbon S; Pliolite. Resistant to acids and alkalies. Slow burning. Inert to metal.
50–300	1.3–2.1	Soluble	G-E Silicone Rubber; Silastic. Withstands from −70 to 500F. Excellent insulator.

RADIOACTIVE MATERIALS . . .

radium series and radioisotope reference sources with decay characteristics; range of beta particles in aluminum, and lead absorption of gamma radiation

A Portion of the Radium-Uranium Disintegration Series

Source	Half-life *hours, days* or *years*	Emission	Maximum Radiation Energy in *million electron volts*		Remarks
			α or β	γ-Ray	
Uranium U_1	4.51×10^9 y	α	4.15–4.23	——	radiography, neutron sources, luminous dials, static eliminators, radioactive resistors, measuring liquid levels, medical applications
Uranium UX_1	24.5 d	$\beta-$, γ	0.11–0.30	0.92	
Uranium U_{II}	2.69×10^5 y	α	4.71–4.78	——	
Ionium Io	8.3×10^4 y	α, γ	4.66–4.81	——	
Radium Ra	1,590 y	α, γ	4.79	0.19	
Radon Rn	3.85 d	α	5.49	——	
Radium RaD (Radio lead)	22 y	$\beta-$, γ	0.03	0.05	
Radium RaE	5.0 d	$\beta-$	1.17	——	
Radium RaF (Polonium, Po)	140 d	α, γ	5.3	——	

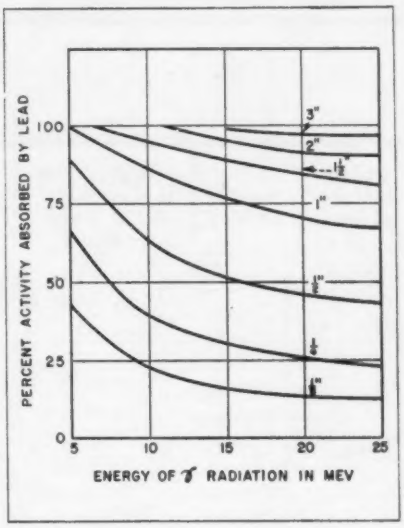
Some Commonly Used Radioisotopes

Potassium K^{42}	12.4 h	$\beta-$, γ	3.5	1.51	heart and nervous diseases
Iodine I^{130}	12.6 h	$\beta-$, γ	0.61–1.03	0.6	
Zinc Zn^{69}	13.8 h	γ	——	0.44	
Sodium Na^{24}	14.8 h	$\beta-$, γ	1.4	1.4–2.8	heart research, gangrene
Bromium Br^{82}	34 h	$\beta-$, γ	0.47	0.55	
Iodine I^{131}	8 d	$\beta-$, γ	0.6	0.37	plant hormones
Calcium Ca^{41}	8.5 d	γ	——	1.1	
Phosphorus P^{32}	14 d	$\beta-$, no γ	1.7	——	circulatory diseases, metabolism
Sulphur S^{35}	87 d	$\beta-$	0.107–0.120	——	penicillin action
Calcium Ca^{45}	180 d	$\beta-$, γ	0.2–0.9	0.7	plant nutrition, bone formation
Zinc Zn^{65}	250 d	$\beta+$, γ	0.4	0.45–1.14	
Iron Fe^{55}	4 y	$\beta+$	0.15	——	anemia, wear of bearings
Cobalt Co^{60}	5.3 y	$\beta-$, γ	0.3	1.3	
Strontium Sr^{90}	25 y	$\beta-$, no γ	0.6	——	
Carbon C^{14}	5,300 y	$\beta-$, no γ	0.145	——	cancer research, plant physiology

Ranges and Maximum Energies of Beta Particles in Aluminum[A]

Radioisotope	Half-life	Range[B] (*mg per cm²*)	Max Energy (*mev*)
Radium Ra^{228}	6.7 years	6	0.053
Rubidium Rb^{87}	6.3×10^{10} y	20	0.132
Columbium Cb^{95}	35 days	30	0.154
Lutecium Lu^{176}	7.3×10^{10} y	48	0.215
Cobalt Co^{60}	5.3 y	80	0.300
Zirconium Zr^{95}	65 d	120	0.394
Iodine I^{131}	8.0 d	210	0.595
Antimony Sb^{124}	60 d	250[C]	0.74
		1,200[C]	2.45
Barium Ba^{140}	12.8 d	420	1.05
Cadmium Cd^{115}	2.33 d	520	1.13
Bismuth Bi^{210}	5.0 d	476	1.17
Strontium Sr^{89}	53 d	730	1.5
Tellurium Te^{129}	70 minutes	800	1.8
Yttrium Y^{90}	65 hours	1,050	2.2
Protactinium Pa^{234}	1.14 m	1,105	2.32
Praseodymium Pr^{144}	17.5 m	1,550	3.07

(A) Abridged from *Nucleonics*
(B) Range is determined by absorption of beta particles in aluminum
(C) β components of the branched decay of Sb^{124}
(D) Reprinted by permission of Tracerlab



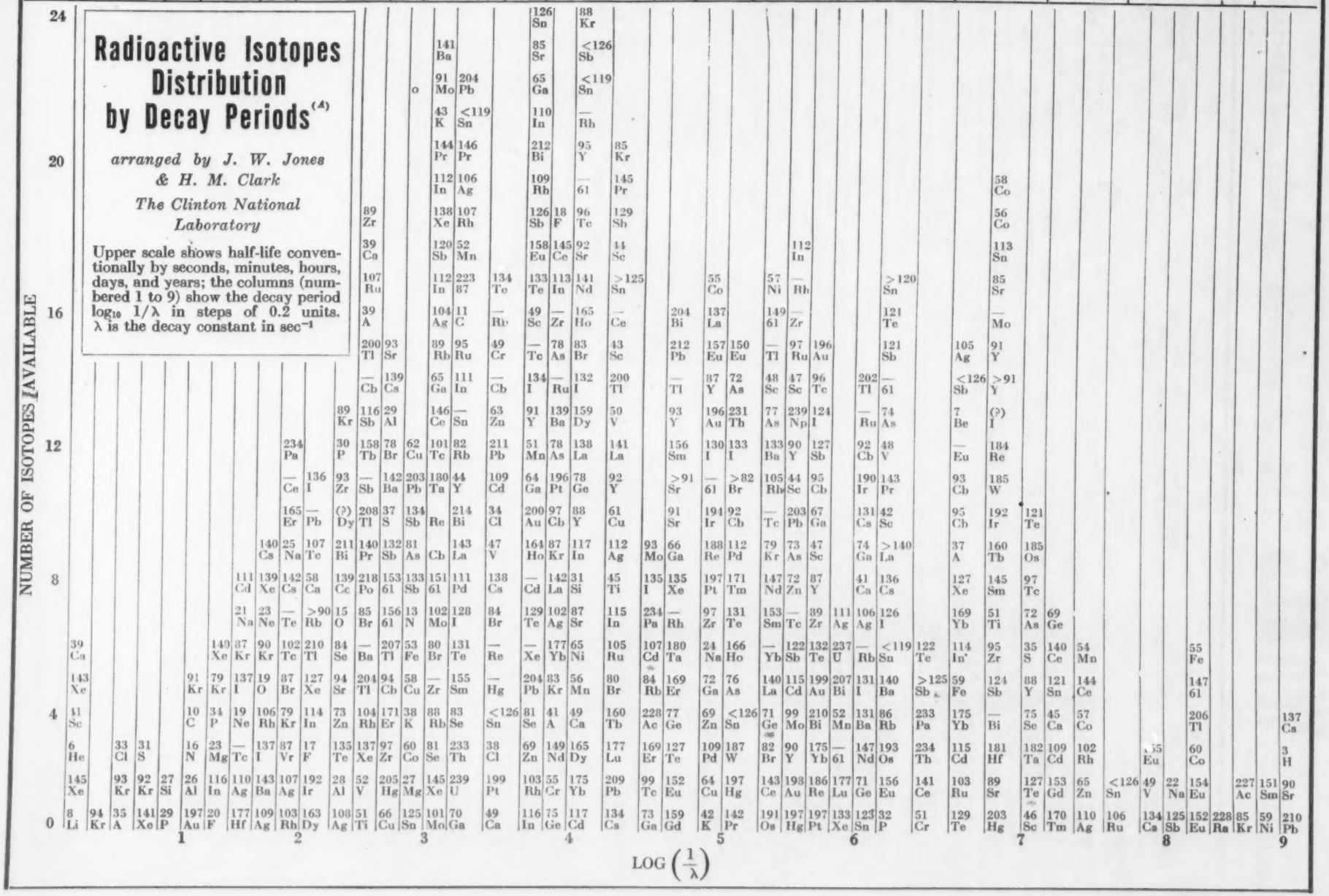
Lead Absorption of Gamma Rays [D]

Radioactive Isotopes Distribution by Decay Periods[4]

arranged by J. W. Jones & H. M. Clark

The Clinton National Laboratory

Upper scale shows half-life conventionally by seconds, minutes, hours, days, and years; the columns (numbered 1 to 9) show the decay period $\log_{10} 1/\lambda$ in steps of 0.2 units. λ is the decay constant in sec^{-1}



WAXES . . . *dielectric, physical and chemical*

Characteristics	Acrawax C, A-355	Amber	Apiezon Wax W	Beeswax, White	Beeswax, Yellow	Cerese Wax, Brown, G	Ceresine 135/8 std Yellow, Syn.	Cenco Sealstix 11430	Halowax 1001	Halowax 1013
Dielectric Constant at 1 megacycle	2.4	2.65	2.65	2.5	2.9	2.27	2.25	3.22	3.7	4.5
Loss Tangent[A] at 1 megacycle	0.002	0.0056	0.0025	0.01	0.01	0.0011	0.0005	0.024	0.0038	0.008
at 10 megacycles	0.0015	0.0068	0.002	0.006	0.0095	0.0006	0.0005	0.027	0.04	0.078
at 100 megacycles	0.0012	0.008	0.0016	0.005	0.0095	0.0004	0.0005	0.025	0.13	0.12
Density at 25 C	0.975	1.06	—	0.95	0.946	0.922[B]	0.881[B]	1.19	1.54	1.65
Melting Point, C	137	—	—	62	45–64	76.7	138	—	—	—
Temperature, Soft, C	—	200	80–90	62–65	—	—	57	80–85	91	119–122
Flash Point, C	285	—	—	—	—	237.8	202	Flammability low	Does not burn	Does not burn
Chemical Resistance to water	Excellent	Excellent	—	—	—	Excellent	—	Excellent	Good	Good
to alcohols	Good	Poor	—	—	—	—	—	Poor	—	—
to hydrocarbons	Poor	Poor	—	—	—	—	—	—	Poor	Poor
to acids	—	—	—	—	—	Good	—	Excellent	Good	Good
to alkalies	—	Good	—	—	—	Excellent	—	Poor	Good	Good
to oxygen	—	—	—	—	—	Good	—	—	Good	Good
Appearance	Hard, brown	Clear-yellow red brown	Black	White	Yellow, opaque	Brown, translucent solid	Yellow and opaque	Light brown	White to pale yellow	Light straw
Composition	Cetyl acetamide	Fossil resin	—	Blanched beeswax, U. S. P.	—	Petroleum wax	Vegetable and mineral waxes	DeKhotinsky cement	Chlorinated naphthalene	Chlorinated naphthalene
Acid Value	<10	—	—	18–24	—	0.01	—	—	—	—
Saponification Value	—	—	—	90–101	—	0.01	—	—	—	—
Solvents	—	—	—	Ether, carbon tetrachl., naphtha, turpentine	—	Benzene, toluene, petroleum solvents	—	—	—	—
Methods of Handling	—	—	(Imported as six-inch sticks)	—	—	Pouring, flash dip, impregnate, surface coating in solution	—	—	—	—
Uses	Insulation, stop-off for plating, improve resistance of varnish to salt spray and water	—	Sealing wax in vacuum systems	Leather dressing, polishes, molding	—	Insulation, moisture-proofing	—	Rigid cement for instruments, apparatus	Dielectric in paper capacitors	Applications where resistance to burning, chemical resistance and high softening point required

[A] Loss Tangent = Loss Factor/Dielectric Constant.
[B] Approximately 15C.
Abridged from Tables of Dielectric Materials, Report V, Laboratory for Insulation Research, MIT, NDRC Contract OEMsr-191.

properties of wax materials for insulating, coating and sealing applications

Halowax 1014	Halowax 11-314	Opalwax	Ozokerite Wax	Parowax	Permafil C26A2	Plicene Cement 11441	135 A. M. P. Wax	132° ASTM Paraffin
4.4	2.94	3.1	2.3	2.25	3.75	2.49	2.25	2.03
0.008	0.00032	0.11	0.0008	0.0002	0.030	0.0025	0.0001	0.00012
0.058	0.00068	0.055	0.0007	0.0002	0.033	0.0021	0.0001	0.00011
0.6	0.0025	0.0027	0.0006	0.0002	0.034	0.0016	0.0001	0.00013
1.76	———	0.98	0.9	0.892[B]	1.31	1.02	0.81[B]	———
———	35–63	86	53	50	———	80	56	56
136–139	———	———	———	———	None	60–65	———	36
Does not burn	Self-extinguishing	———	Flammability high	200	———	———	213	204–218
Good	Excellent	———	Excellent	Excellent	Good	Excellent	Excellent	Excellent
———	———	———	———	———	———	Good	Good	———
Poor	———	———	———	———	———	———	Poor	———
Good	Good	———	Excellent	Good	Good	Excellent	Good	———
Good	Good	———	Excellent	Excellent	Good	Excellent	Good	Good
Good	Good	———	Good	Good	Good	———	———	Good
Pale yellow	White, crystalline, opaque	Pearl white	Opaque, brown-black	White	Amber, transparent	Opaque, black	Yellow	White solid, translucent
Chlorinated naphthalene	Dichloro-naphthalene	Hydrogen-ated castor oil	Native paraffin	Petroleum wax	Cross-linked addition polymer	———	Low-loss paraffin	Paraffin wax
———	———	<2	———	Nil	———	———	———	Nil
———	———	175–185	———	Nil	———	———	———	Nil
———	———	———	———	Benzene toluene, petroleum solvents	———	———	———	Hydrocar-bons and chlorinated solvents
———	———	Surface coats; emulsify, spread and dry	Impregnation	Pour, flash dip, impreg-nate; com-pression molding, sur-face coating	Casting or impregnation	———	Pour, flash dip, impreg-nate, com-pression molding	Surface coat, impregnate
Applications where resis-tance to burning chemical resistance and high softening point required	———	Insulation, make fibrous materials grease, oil and water-proof	Waterproof insulation, paper, temporary sealing	Coating and sealing	Coil impreg-nation, laminated materials	———	Temporary sealing, paper impregna-tion	Water-repellant coatings, impregnate fibrous materials

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CONSULTING ENGINEERS

ELECTRONICS presents, in this directory of consulting engineers active in its field, the results of a survey. The first column lists names and addresses. An asterisk after a name indicates that patent matters are handled, in addition to the work noted in subsequent columns.

The second and third columns indicate the type of consulting work done. Numbers in these columns provide a further breakdown, and are explained at the bottom of this page. Some types of work have been consolidated. For example: test equipment consultants are listed under instrumentation (5), and radiation consultants are listed under wave propagation (11).

Name	Communications	Industrial	Design	Models	Area
ABISLAIMAN, ALBERT P. O. Box 4, Havana, Cuba	4		•		Cuba
ADAIR, S. E. 4500 Thorndale, Chicago, Ill.	10-25	1-2	•		300 miles
AERO-MARINE RADIO LABORATORY* Foster Field, Stonington, Conn.	17	17	•		75 miles
AIRCRAFT ELECTRONICS ASSOCIATES 1031 New Britain Ave., Hartford, Conn.	4-10	17-26		•	200 miles
AGRICULTURAL AVIATION CO. Colusa, Calif.		1-2-3	•	•	national
ALLIED RESEARCH, INC.* 667 Blaine, Detroit, Mich.	12-17-20	1-5-6-27-29	•	•	national
ALLISON ASSOCIATES* 2254 S. Sepulveda Blvd., Los Angeles, Calif.	10-17	1-2-5-21-26	•	•	national
AMERICAN INVENTORS SERVICE CO.* 656 Spitzer Bldg., Toledo, Ohio	15	15		•	national
AMY, ACEVES & KING, INC.* 132 Nassau St., New York, N. Y.	1-10-25-30		•		national
ANDERS, JOHN F. Kitchawan, N. Y.	17-21	•		•	national
ANDERSON, LOUIS L. 412 Norton Bldg., Louisville, Ky.	17	17		•	national
ANDERSON & MERRYMAN 715 American Bank Bldg., Lake Charles, La.	4-10-26-27		•		national
ANDREWS, L. W. 1927 College Ave., Davenport, La.	4-10-11-12	17-25-30	•		national
APPLIED SCIENCE CORP. OF PRINCETON U. S. Highway No. 1, RFD 4, Trenton, N. J.	5	8		•	national
ARCHETTI, ALDO 464 Woodcliff Ave., Hudson Heights, N. J.	4-12-25			•	10 miles
ARDNER & ARDNER 2625 N. Meridian St., Indianapolis, Ind.		1-2-5-17	•	•	state
ARNOLD-STUBENBORD, INC. 220 Myrtle Dr., San Antonio, Texas		8-9	•	•	national
AUDIOPHONE 325-19th St., Oakland, Calif.	4-10	30	•	•	100 miles
AUSTIN, A. O. Box 109, Barberton, Ohio	7	7	•		national
AUTOMATIC ELECTRIC CO. 1033 West Van Buren St., Chicago, Ill.	10	10	•		national
BACON, J. W. 2001 Bay View Dr., Hermosa Beach, Calif.		1-12	•	•	state
BALCO RESEARCH LABS.* 580 Market St., Newark, N. J.	24	8	•	•	national
BANKER ELECTRONICS 688 Main Ave., Passaic, N. J.	5	5-17		•	national
BARRET, INC., WILLIAM M. 909 Giddens Lane Bldg., Shreveport, La.		9	•		international
BARRON, JOHN 1052 Warner Bldg., Washington, D. C.	4-10-25		•		national
BARRY CORPORATION, THE 179 Sidney St., Cambridge, Mass.	2	2	•	•	national
BATCHELOR, JOHN C.* 52 Wall St., New York, N. Y.	15	15		•	national
BATCHER, RALPH R. 240-02 42nd Ave., Douglaston, N. Y.		5	•	•	national
BEARDSLEY, W. S. Box 573, La Porte, Texas	5-10			•	200 miles
BENNS, JR., WM. P. O. Box 2468, Birmingham, Ala.	4			•	1500 miles
BERKELEY SCIENTIFIC CO.* 601 Nevin Ave., Richmond, Cal.		1-2-5-8-9-17-20-23	•	•	national
BERNARD, S.* 23-28 41st Ave., Long Island City, N. Y.		1-2-3-5-8-12-15-17-19	•	•	national
BERNARD ASSOCIATES 4304 Melrose Ave., Hollywood, Calif.	4		•		national
BERRY, JAMES S.* P. O. Box 308, Savannah, Tenn.		1-2-12-17	•	•	state
BLAIR, W. Locust Point Rd., Locust, N. J.	8	8	•		200 miles
BLOEMSMA, IR. J.* 551 Mient, The Hague, Holland	10-11	12-26	•		Holland
BOND RES. LABORATORIES, INC. 80-84 Winslow Ave., Somerville, Mass.		1-2-20-24	•	•	national
BOSSARD, G.* 21350 Lovain Rd., Cleveland, Ohio		1-2-5-13-17-20	•		national
BOYCE, H. JAY* 313 Main St., Danbury, Conn.		5-17-20-21		•	300 miles

(1) Electrical (2) Mechanical (3) Hydraulic (4) Broadcasting (5) Instrumentation (6) Chemical (7) Insulation (8) Applied Physics (9) Geophysics (10) Communications (11) Wave Propagation (12) Radio Receiver Design (13) Recording (14) Welding (15) General (16) X-Ray (17) Electronic Control (18) Transmission Line (19) Aircraft Antennas (20) Production Engineering (21) Automatic Weapons (22) High Speed Photography (23) Spectrograph (24) Components (25) Television (26) Radar (27) Medical (28) Ceramics (29) R. F. Heating (30) Acoustics

* Handle Patents

CONSULTING ENGINEERS continued

Name	Communications	Industrial	Design	Models	Area
BOZOIAN, M. 702 S. 5th St., Ann Arbor, Mich.		1-5-17	•	•	500 miles
BREON LABORATORIES 1520 Evergreen Rd., Williamsport, Pa.	1-10	27-29		•	state
BROADCASTING ENG. SERVICE P. O. Box 1387, Shreveport, La.	4		•		national
BROWN, C. 66 Westgate, Cambridge, Mass.		5	•	•	state
BROWNELL, H.* 188 W. 4th St., New York, N. Y.		1-5-8-12-17-27		•	300 miles
BRUCKMAN, F. E. R. F. D. Rt. No. 1, Norwood, N. Y.		1-17	•		state
BRYANT, F. D.* 173 Longvue Dr., Wethersfield, Conn.		1-2-14-20-29	•	•	state
BURDEN, B. C. Box 931, Lincoln, Nebraska	1		•	•	national
BUCK, G. 306 Monroe St. S., Hutchinson, Minn.	1		•		state
BUILDER, G., ESQ.* 7 Appian Way, Burnwood, NSW, Australia	15	15	•	•	state
BUMSTEAD, RALPH W.* 624 Maple St., Westfield, N. J.	10-17	20-25	•		100 miles
BURCHETT, C. W. 172 Golden Gate Ave., San Francisco, Calif.	1		•		state
BUTMAN, CARL H. National Press Bldg., Washington, D. C.	4				national
CAIN, L. H. 3610 S. Barington Ave., Los Angeles, Calif.	4-5-10-17		•		state
CALIFORNIA LABS.* 452 Clifton St., Oakland, Calif.		5		•	state
CANALE ING. MANUEL R. ELECTRICAL ENGINEERING CO. Box 1547, Nogales, Ariz.	1-4-10-25	12-16-27-30	•		national
CANADIAN RES. INSTITUTE 46 St. George St., Toronto, Ont., Canada	1-4-5-10-17	6-8-9-12-27-29-30	•	•	national
CANISTEO ELECTRONIC INSTRUMENT LAB. 30 E. Main St., Canisteo, N. Y.	4-5-10-11-12	1-17-21-25-26-27	•	•	national
CENTRO RESEARCH LABS. 9 Rockefeller Plaza, New York, N. Y.		1-5-6-12-17-27			
CHAMBERS & GARRISON 1519 Connecticut Ave., Washington, D. C.	4-10-11-25		•		national
CHAPMAN, R. Rt. 6, Box 41, Ft. Worth, Texas	4-10		•		state
CHILDS, EARL 2822 N. Broadway, Los Angeles, Calif.		17		•	50 miles
CINCINNATI RESEARCH CO. 6431 Montgomery Ave., Cincinnati, Ohio	6	6		•	national
CIRCUITO CMQ Havana, Cuba	4		•	•	national
CLEARY, LEO H. 2726 Conn. Ave., N. W., Washington, D. C.		1	•		1000 mile
COLES, W. A. 412 Spruce Ave., Upper Darby, Pa.		12-27-29	•	•	national
COLLUP, DOYLE 3300 Mt. Vernon, Ft. Worth, Texas	1-4-10		•	•	500 miles
COLWELL, R. E. 518 W. Maple St., Deshler, Ohio		5-17		•	state
COMMERCIAL AMPLIFIER CO. 6629 Drexel Ave., Chicago, Ill.	1-4-10-12-25-30	17	•		200 miles

Name	Communications	Industrial	Design	Models	Area
COMMERCIAL RADIO EQUIPT. CO. 1319 F St., N. W., Washington, D. C.	4		•		national
COMMONWEALTH ENGINEERING CO. OF OHIO 1771 Springfield St., Dayton, Ohio		1-2-3-5-6-8-12-15-17-20-30	•	•	national
CONLON ELECTRIC CORP. 117 South St., Baltimore, Md.		1-2-4-17	•		national
CONSOLIDATED MANAGEMENT CONSULTANTS 521 5th Ave., New York N. Y.		1-20	•		national
CONTENT, EDWARD J. Roxbury Rd., Stamford, Conn.	4-10-25-30		•		national
CONTROL ENGINEERING CO.* 7631 Jos Campau, Detroit, Mich.	1	2-3-17		•	national
CORNELL, HOWLAND, HAYES & MERRYFIELD 212 Rennie Bldg., Corvallis, Ore.	•	1-3	•		state
COWLES, JOHN* 349 E. Cliveden St., Philadephia, Pa.		1-2-3-5-6-14-26-29-30	•	•	national
CRAWFORD, THOMAS J.* 3726 Kipling Ave., Berkley, Mich.		2-14-20	•		1000 miles
CREUTZ, JOHN Bond Bldg., Washington, D. C.	4-11-25		•		national
CROWLEY & ASSOC., INC., GRAHAM* 473 York Rd., Jenkintown, Pa.	5-6-29		•		national
A. EARL CULLUM, JR.—CONSULTING RADIO ENGINEERS Dallas, Texas	4		•		national
DAVIES LABORATORIES, INC., THE Box 65, College Park, Md.	15	15		•	50 miles
DAVIS, E. S.* 422 N. E. River Dr., Ft. Lauderdale, Fla.	17	5-8		•	national
DAVIS, GEORGE C. 504 Munsey Bldg., Washington, D. C.	4		•		national
DAVIS, R. L. 535 Fountain St., Grand Rapids, Mich.	1		•		200 miles
DEIGERT & YERKES 3211 "O" St., N. W., Washington, D. C.	30		•		national
DELTA ELECTRONIC EQUIPT. CO. 3413 Carondelet St., New Orleans, La.	5-10-25	12-16-17-27		•	300 miles
de la WAR, G. W. Kingston Yarnell Hill, Oxford, Eng.		27		•	
DE MORNAY BUDD, INC.* 475 Grand Concourse, New York, N. Y.	•	1-2	•	•	national
DE RYDER, H. 104 Demarest Ave., Bloomfield, N. J.	25	12		•	national
DESIGNERS FOR INDUSTRY Box 47, Bennett Rd., Strongsville, Ohio	1-2-12-26	15-17-20	•	•	500 miles
DESIGNERS FOR INDUSTRY, INC.* 2915 Detroit Ave., Cleveland, Ohio	1-10-12-17-26	2-15-18-20-29	•	•	national
DIVER, M. L. Box 1016, San Antonio, Texas		1	•		state
DOEH DEVELOPMENT CO.* 1588 Sterling Pl., Brooklyn, N. Y.	12		•		25 miles
DOELCAM CORP. 437 Cherry St., W. Newton, Mass.		5		•	national
DONALDSON ELECTRONICS LABORATORY* P. O. Box 1486, San Antonio, Texas		9-17-25-26		•	state
DRAUGHONS SCHOOL OF RADIO & ELECTRONICS Little Rock, Ark.	10	17	•		200 miles
EASTERN DEVELOPMENT CO.* 15 E. 22nd St., New York, N. Y.		2	•		500 miles

Name	Communications	Industrial	Design	Models	Area
EBEL, JAMES A. 1st National Bank Bldg., Peoria, Ill.	4		•		national
EDWARDS, BOWER & POOL* 63 Wall St., New York, N. Y	•	1-5			national
EDGERTON, GERMESHAUSEN & GRIER 77 Massachusetts Ave., Cambridge, Mass.		1-5-17-22	•	•	national
EHRLICH, CHARLES N. 130 W. 12th St., New York, N. Y.		1-12-24-29	•		100 miles
EILENBERGER, S.* 6309 27th Ave., Kenosha, Wisc.		1-2-5	•	•	national
ELEC. COMMUNICATION CO. 765 Clementina St., San Francisco, Cal.	10			•	state
ELECTRODYNE CO.* 899 Boylston St., Boston, Mass.	1-5	2-8-17-27	•	•	national
ELECTRO IMPULSE LAB. P. O. Box 250, Red Bank, N. J.	5	8-27-29		•	national
ELECTRONIC DEVELOPMENT LABORATORY 2655 W. 19th St., Chicago, Ill.	•	5		•	national
ELECTRONIC ENGINEERING INC.* S. 1212 Monroe St., Spokane, Wash.		1-2-5-6-17		•	national
ELEC. ENGR. & SUPPLY CO. Box 178, Burlington, Iowa	4-10-30	16	•	•	1000 miles
ELECTRO-MECH. RES., INC.* Ridgefield, Conn.	1-5-10-12	2-9-17		•	national
ELECTRONIC ASSOCIATES, INC.* 61 Brighton Ave., Long Branch, N. J.	10-12-26	5-17-18		•	1000 miles
ELECTRONIC DEVELOPMENTS (PTY), LTD. 8 Wolhuter St., Jeppe, Johannesburg, S. Africa	10-12	17		•	
ELECTRONIC ENGR. CO. OF CALIF. 2008 W. 7th St., Los Angeles, Calif.	4-5-10-12-25	17-22-26-29	•	•	national
ELECTRONICS ENGR. CO. 104 Tyson Bldg., Montgomery, Ala.	4-10-12		•		300 miles
ELECTRONIC RES. ASSOC.* 2301 El Camino Real, San Mateo, Calif.	10	17		•	national
ELECTRONICS RESEARCH, INC.* P. O. Box 327, Evansville, Ind.	4-19	•		•	national
ELECTRON-MACHINE CO.* 2 East End Ave., New York, N. Y.	17	17		•	1000 miles
ELLINGTON, W. M. 724 Chestnut St., Jackson, Miss.	4-10		•		state
ELLSWORTH, A. R. 8469 Hollywood Blvd., Hollywood, Calif.	12-15-20			•	100 miles
ELM LABS 20 S. Broadway, Dobbs Ferry, N. Y.	1-10-12	2-15-24	•	•	national
EMPIRE LABS 39-01 Main St., Flushing, N. Y.	10-12	17-27-29	•	•	national
EMPIRE PROJECTOR CORP. 60 McClean Ave., Yonkers, N. Y.	•			•	national
ENGINEERING DEVELOPMENT LABORATORY 2326 S. Michigan Ave., Chicago, Ill.	•	12		•	national
ENGINEERING LABORATORIES, INC.* Box 349, Tulsa, Okla.		5-9-17-30		•	national
ENGINEERING RES. & DEVEL. CO.* P. O. Box 166, Hinsdale, Ill.		15		•	national
ENGINEERING RESEARCH ASSOCIATES, INC. 1129 Vermont Ave., N. W., Washington, D. C. 1902 W. Minnehaha Ave., St. Paul, Minn.	1-5-10	2-6-8-15-17		•	national
FANNING, W. N.* 1539 Morton, Alameda, Calif.	21			•	national
FERRAMENTA, M. Rue Joaquim Tavora 300 Santos Est De, Sao Paulo, Brazil	2		•		100 miles
FITZGERRELL, G. C. 1658 Lucile Ave., Los Angeles, Calif.	10	5-17		•	200 miles
FORBES, K.* Box 817, Erie, Mich.		12		•	400 miles
FOSS, INC., WM. L. 927 15th St., N. W., Washington, D. C.	4	4	•		national
FRANCIS, J. S.* 222 N. Michigan Ave., Chicago, Ill.		2-12-13-15-20-21	•	•	national
FRANKS, C. J. Box 92, Boonton, N. J.	10	5-15		•	100 miles
FROMMER, JOS. C. 1525 Teakwood Ave., Cincinnati, Ohio	5-8-17		•	•	250 miles
GALANTY, HAROLD 287 Conklin Ave., Hillside, N. J.		1-2-5-12-17-20	•		250 miles
GEFFNER COMPANY, JOS. Weirton, W. Va.		23		•	national
GENERAL DEVELOPMENT CO.* 54 Rue Du Pepin, Bruxelles, Belgium	1-5-10-25	12-17-20-29		•	Belgian, Congo Belgium, France, Holland
GENERAL INSTRUMENT & ENGINEERING Washington, D. C.	•	1-8-17			
GILLE BROS. 1108 N. Lillian Way, Hollywood, Cal.	5-25			•	national
GILLETT, GLENN D. & ASSOC. National Press Bldg., Washington, D. C.	4		•		national
GLOBE PRODUCTS CORP. Bridgeport, Conn.		5-15			
GLOVER, RALPH P. 1024 Superior St., Oak Park, Ill.	10-30	1-5	•		national
GODLEY CO., PAUL P. O. Box J, Upper Montclair, N. J.	4-10-25	5-11-15-19-23	•		national
GOLDSMITH, A. N.* 597 5th Ave., New York, N. Y.	4-10-25	1	•		national
GOLDWATER, F. J. 200 West 20th St., New York, N. Y.	17			•	100 miles
GLOBE DEVELOPMENT CO.* 1970 E. 18th St., Brooklyn, N. Y.	4-10-30		•	•	150 miles
GORDON CO., CLAUDE S. 3000 S. Wallace St., Chicago, Ill.		5	•		national
GREER, WILLIAM N. P. O. Box 4919, San Juan, Puerto Rico Office: 257 Tetuan St., Rm. 10	4-10-25-30	1-17		•	Central Amer.
GREIBACH RESEARCH AND DEVELOPMENT LABS.* 80 Pryor Terr., New Rochelle, N. Y.	•	8-15	•	•	200 miles
GRETHER, INC., WM. P. 6 E. Davie St., Raleigh, N. C.	10				800 miles
GRIER, M. S.* 6934 Amigo St., Reseda, Calif.	8	8	•		25 miles
HAHN, G. 1515 Halsted St., Chicago Heights, Ill.	10		•		100 miles
HALL, R. BENSON* 6431 Euclid Ave., Hammond, Ind.		15	•		50 miles
HALL, V. C. 835 Hope St., Springdale, Conn.		8	•		national
HANSEN, W. W. 515 Gerona Rd., Stanford U., Calif.	8				national

CONSULTING ENGINEERS continued

Name	Communications	Industrial	Design	Models	Area
HALL, LESLIE R. 9 Shepley St., Auburn, Maine	4				500 miles
HANSON-GORRILL-BRIAN, INC. Meadow Lane, Glen Cove, N. Y.	17	17		•	national
HARDEN, PAUL A. 529 E. Colorado St., Pasadena, Calif.	4-10-11-17		•		Pacific Coast
HALINTON, HARRY 612 North Michigan Ave., Chicago, Ill.	4-10	5-17			200 miles
HARROLD, W. 101 N. 45th St., Seattle, Wash.		5		•	national
HARVEY, H. L. 2938 St. Paul St., Baltimore, Md.		1-2-5-6-17-22	•	•	national
HATFIELD, J. B. 936 35th Ave., Seattle, Wash.	4		•		500 miles
HATHAWAY INSTRUMENT CO. Box 4178, Denver, Colorado		1-2-5-9-17	•	•	national
HATTON & CO., ARTHUR T. 17 Knollwood Rd., W. Hartford, Conn.		1-5-17			500 miles
HAYNES, A. 2227 S. 10th Ave., Broadview, Maywood, Ill.		15	•		national
HAZELTINE ELEC. CORP.* 1775 Broadway, New York, N. Y.	12	1	•	•	national
HAUSNER, HENRY H.* 155 Riverside Drive, New York, N. Y.	•	1-7-28	•		national
HEILAND RESEARCH CORP. Box 360, Denver, Colo.		9		•	national
HELVEY, OLIVER J. 5110 Deane Ave., Los Angeles, Calif.		27	•		national
HENDERSON ELECTRIC ENGR. CO. Box 2615, Greenville, Miss.		5	•	•	national
HERBOLD, ROBERT J. 2510 S. Columbine St., Denver, Colo.		8		•	national
HIGGY, ROBT. C. Ohio State Univ., Columbus, Ohio	4		•		state
HILLYER INSTRUMENT CO., INC. 120 E. 13th St., New York, N. Y.		17-21		•	national
HOBBS, MARVIN 2414 W. Lawrence Ave., Chicago, Ill.	12-17-25		•	•	national
HOEHLEIN, F. W. 121-17 12th Ave., College Pt., N. Y.		15	•		25 miles
HOGAN, JOHN V. L. 730 5th Ave., New York, N. Y.	10	•		•	national
HOLEY & HILLEGAS 2836 Tupilo St., S. E., Atlanta, Ga.	4		•		national
HOLLEY, ARMANDO Calle Constitution 097, Santiago, Chile, S. A.	10	10		•	national
HOLWAY & ASSOC., W. R. 302 E. 18th St., Tulsa, Okla.	1	1-3			national
HORNE, C.* 45 Earls Court Rd., London, W. 8, England		6-16-23-27	•	•	
HORNER, G. EDWARD 188 Paine Ave., Irvington, N. J.	12	•	•		25 miles
HOUSTON CORP. 11801 W. Olympic Blvd., W. Los Angeles, Calif.	26		•		national
HOWELL, B. 212 LaFrance Ave., North, Alhambra, Calif.	1-2-5-17	1-2-5-17	•		50 miles
HOWEY, W. C.* 5 Winthrop Sq., Boston, Mass.	10				international
HUFFMAN LABORATORIES* 17 Watchung Plaza, Montclair, N. J.	10-25	1-17-29	•	•	national
HULBERT ENGINEERING CORP. 903 Clyman St., Watertown, Wisc.		2-3-29		•	national
HURST LABS. 514-37th St., N., St. Petersburg, Fla.		6-8	•		state
HUTCHESON, GUY C. 1100 W. Abram St., Arlington, Texas	4		•		national
I. B. M. CHUNG CHIN KAO 334 W. 85th St., New York, N. Y.	10				national
IND. DEVELOPMENT ENGR. ASSOC., INC. 4125 E. 10th St., Indianapolis, Ind.	10-25-30	2-12	•	•	250 miles
INDUSTRIAL RES. LABS. 2412 Asquith St., Baltimore, Md.		1-2-5-17-21-27-29		•	national
INST. OF INDUST. RESEARCH* 1604 Milan Bldg., San Antonio, Texas		15	•	•	national
INTERCONTINENT ENGINEERING CORP. 37 Wall St., New York, N. Y.	4-10	1-20-24	•	•	international
INT. ELECTRONICS LABORATORIES* 15 W. 47th St., New York, N. Y.	•	17		•	national
JACKSON & MORELAND 31 St. James Ave., Boston, Mass.		12	•		1000 miles
JANSKY & BAILEY National Press Bldg., Washington, D. C.	4-10-11-12-25-26		•		
JARVIS, KENNETH W.* 1140 Cherry St., Winnetka, Ill.	10	1-2-5-12-17-26	•	•	national
JASPERT, GEORGE H. Little Bldg., 80 Boylston St., Boston, Mass.	4-25				500 miles
JETER, G.* 71 Walnut St., Montclair, N. J.		20-29	•		150 miles
JOHNSON, G. R. Box 9, Estevan, Sask., Canada		9	•	•	national
JOHNSON, J. KELLY Suite 208, 55 W. 42nd St., New York, N. Y.	1-5-10-12-17-25	•	•	•	national
JOHNSTON, RICHARD 351 N. Woodward, Birmingham, Ala.	30			•	50 miles
JONES, CARY B. P. O. Box 1059, Palo Alto, Calif.	•	8		•	national
JUPE, JOHN H., A. M. I. E. E. 8 Clock House Forty Hill, Enfield, Eng.	10	1-5-17-29			national
KEAR & KENNEDY 1703 "D" St., N. W., Washington, D. C.	4-10-11		•		national
KEEFE, F. M. 75 Berkshire St., Indian Orchard, Mass.		5-12-17	•	•	100 miles
KEEL, JOHN J. Earle Bldg., Washington, D. C.	4-10-25-30	2-11-12	•		national
KEINATH, GEORGE* 36 Knollwood Dr., Larchmont, N. Y.		1-5	•		national
KELLEY, LEO A.* 34-38 87th St., Jackson Heights, N. Y.	1	1			national
KENYON INSTRUMENT CO. 1345 N. Y. Ave., Huntington, N. Y.		3-17-22		•	national
K & K ENGINEERING CO.* Bolton, N. Y.		1-2-3-5-17-23		•	national
KLEINBERGER, RICHARD C. 1 East Post Road, White Plains, N. Y.		1-17-29			state
KNOBEL, MAX* 663 Beacon St., Boston, Mass.		15		•	national

Name	Communications	Industrial	Design	Models	Area
KOKOMO ENTERPRISES 102½ S. Main St.—Box 270, Kokomo, Ind.	10	20-22		•	national
KRAMER, M. 5 W. 86th St., New York, N. Y.		27	•	•	1000 miles
KRUEGER, A. M. 2033 Gates Ave, Brooklyn, N. Y.		1-17	•		state
KRUSE, CHARLES C. Glen Cove, Pewaukee, Wisc.		22	•	•	state
LABORATORY FOR ELECTRONICS, INC.* 11 Leon St., Boston, Mass.	•	8		•	national
LA HUE, PHILIP 3215 E. 34th Ave., Denver, Colo.		1-8-14-17	•	•	national
LANGE, E.* 3608 Forest Hill Rd., Baltimore, Md.	5-12	1-8-17-24	•		400 miles
LANGLAND & ASSOC., G. H.* P. O. Box 405, Mill Valley, Calif.		2		•	100 miles
LARSON, THOR 2851 9th Ave. N., St. Petersburg, Fla.		1-15-17-22		•	state
LAWTON PRODUCTS CO. 624 Madison Ave., New York, N. Y.		1-2-5-8-12-17-27-30		•	100 miles
LEATHAM, W. G. P. O. Box 11, Lower Hutt, N. Z.	10		•		national
LEBEL, C. J.* 370 Riverside Drive, New York, N. Y.	5	20-27-30	•	•	national
LECTRONIC RESEARCH LABS. Howell & Hegerman Sts., Philadelphia, Pa.		5-22		•	national
LEE, M. 148 Lafayette Ave., Brooklyn, N. Y.	12			•	national
LENT, W. C. 1200 18th St., N. W., Washington, D. C.	4		•		national
LERU LABORATORIES 360 Bleeker St., New York, N. Y.	17	26		•	national
LESTER, JOHN M. 15 Elk St., Hempstead, N. Y.					
LINCOLN, E. 345 Madison Ave., New York, N. Y.		1-7	•		national
LINDERMAN CORP., G. B.* 4767 Indiana Lane, N. W., Washington, D. C.		1-2-8-17		•	800 miles
LINDSAY, JR., WM. W. 230 Thurston Ave., Los Angeles, Calif.		II		•	national
LITTLE, INC., ARTHUR D.* 30 Memorial Dr., Cambridge, Mass.		15		•	national
LOEW, T. Room 2608, 350 5th Ave., New York, N. Y.		2-12-15	•	•	500 miles
LOHNES & CULVER Munsey Bldg., Washington, D. C.	4		•		national
LONGORIA, ANTONIO 6007 Euclid Ave., Cleveland, Ohio	•	1-14-17-29	•		national
LUBBERT, G.* 5609 Merville Ave., Baltimore, Md.	10	1-2-5-12-17-20	•	•	national
LUKE, H. N.* 2113 Somerset Place, Oklahoma City, Okla.		9-17-20		•	national
LUNDY, CLARENCE 428 Boulevard, Bayonne, N. J.	1-12	2-8-17-27		•	national
LYON, HENRY H. 4004 Jefferson St., Hyattsville, Md.	4-25		•		100 miles
MAGGIO, C. 6420 New Utrecht Ave., Brooklyn, N. Y.	5	5	•	•	50 miles
MASS. INST. OF TECHNOLOGY Cambridge, Mass.	26				national
McCACHREN, WINFIELD S. 809 Windmere Ave., Drexel Hill, Pa.	25			•	national
McCREARY, H. J.* 320 Lewis Ave., Lombard, Ill.	1	1	•	•	national
McINTOSH, FRANK H. 710 14th St., N. W., Washington, D. C.	4	12-17-25-26-29-30	•		national
MAXSON CORP., W. L.* 460 W. 34th St., New York, N. Y.		15		•	600 miles
McKEY & ASSOC., DIXIE B. 1730 Conn. Ave., Washington, D. C.	4-10-11-12-19-25		•		national
McNARY & WRATHALL* 983 National Press Bldg., Washington, D. C.	4-10-11-25		•		national
McNEAL, J. D. 784 Quinnipiac Ave., New Haven, Conn.	•	17-29		•	state
MAKI, GEORGE J.* Moraga, Calif.	10			•	national
MARSHALL, T. 73 Vaughan St., Portsmouth, N. H.	10-12-30		•		state
MAST DEVELOPMENT CO., INC.* 2110 E. 11th St., Davenport, Iowa		2	•	•	national
MAY, RUSSELL P. 1422 "F" St., N. W., Washington, D .C.	4-10-11-25		•		national
MELPAR, INC. 718 5th St., N. W., Washington, D. C.	1			•	national
MEASUREMENT ENGR. LTD. 61 Duke St., Toronto, Canada	4-5-10		•	•	national
MEREDITH, WILLIAM* Blackburn Bldg., Ottawa, Canada	10	1-2-15-17	•		national
METCALF & EDDY 1762 Commonwealth Ave., Brighton, Mass.		1-3-17	•		national
MICHEL, JOHN* 15 Park Row, New York, N. Y.	10	1-17-29			national
MIDLAND ASSOC. 1959 Lunt Ave., Chicago, Ill.	8-10-20-25		•		state
MILWAUKEE COUNTY H'WAY COMM. Court House, Milwaukee, Wisc. N. S. Rich		1-17	•		50 miles
MITTELMANN, E. E. 549 West Washington Blvd., Chicago, Ill.		8-12-17-29		•	national
MODEV CO. 2039 Salem Ave., Dayton, Ohio		1-2-3-5-8-12-27	•	•	national
MODIE, E. Barnesville, Ohio		1			
MOEN, ESTEN Fosston, Minn.	12-25		•		10 miles
MORRISON, M.* 153 5th Ave., New York, N. Y.	10-12-15	1-2-5	•	•	1000 miles
MURRAY, ALBERT F.* 4707 Windom Pl., N. W., Washington, D. C.	25		•		national
NAKEN, WM. 1635 W. Pratt Blvd., Chicago, Ill.		20-22			
NARIMATSU, D. T. G. P. O. Box 996, New York, N. Y.		5	•		state
NATIONAL ELECT. LABS., INC. 200 King St., Alexandria, Va.	10	•		•	300 miles
NATIONAL RADIO RESEARCH LABORATORIES 74 W. 68th St., New York, N. Y.	1-4-5-10	8-12-17-24-30	•	•	national
NEUMAN, LEONARD J.* 943 Mellie Esperson Bldg., Houston, Texas	5	5	•	•	national

CONSULTING ENGINEERS continued

Name	Communications	Industrial	Design	Models	Area
NEW PRODUCTS MFG., INC. 631 Wayne Ave., Dayton, Ohio	1-10-17	2-5-20-21		•	national
NIAGARA ELECTRON LABS. Box 141, Andover, N. Y.		5-6-17	•	•	national
NIKIRK, THOMAS 549 S. Berkeley Ave., Pasadena, Calif.	10	29		•	100 miles
NOEL MFG. CO., THE 136-138 E. 122nd St., New York, N. Y.		2	•	•	national
NORTH AMERICAN RESEARCH LABORATORIES, INC. 156 Harold Ave., Fanwood, N. J.	•	5-17	•	•	national
NOVIK, M. S. 30 Rockefeller Plaza, New York, N. Y.					
OCCHIOGROSSO, T. 84 Barker Ave., Eatontown, N. J.	25	•	•	•	100 miles
O'REILLY, R.* 3404 Beach Dr., Seattle, Wash.	10	12		•	Alaska and statewide
OSWALT, A. K. 620 7th Ave. N., Texas City, Texas	10	17		•	state
OSTERMOOR, A. G. Whaley Lake Apaireies, Holmes, N. Y.	30			•	national
MESSRS. OXLEY DEVELOPMENT CO. LTD.* 28 Meeting House Lane, Ulverston, Lancs., England	7-10-12-24		•	•	national
PACENT ENGR. CORP. 79 Madison Ave., New York, N. Y.	10-12-25-26		•		national
PACIFIC ELECTRONICS 1612 N. Hill Ave., Pasadena, Calif.	4-10-12-17		•		national
PALMER COMPANY, FRED A. Union Trust Bldg., Cincinnati, Ohio	4-25				national
PARDEE & ASSOC., HARVEY S.* 549 W. Washington Blvd., Chicago, Ill.		15	•		national
PATRICK RESEARCH & DEVELOPMENT LABS. 5206 N. Keystone Ave., Indianapolis, Ind.		20		•	national
PATTERSON CO., C. J. 4722 Broadway, Kansas City, Mo.	10	5		•	national
PERCO, INC.* 1133 S. High St., Columbus, Ohio	•	22		•	state
PERRIN, JOSEPH* 95 Liberty St., New York, N. Y.		3		•	350 miles
PETRY, S. H.* 3016 Central St., Evanston, Ill.		2-12-20-27	•	•	100 miles
PHILBRICK RESEARCHES, INC., GEORGE A. 230 Congress St., Boston, Mass.		5	•	•	national
PICKARD & BURNS 66 Needham St., Newton Highlands, Mass.	5-8-10-11		•	•	national
PIERCE, F. W. 2415 19th Ave., Rock Island, Ill.	15	15		•	500 miles
PIONEER ELEC. & RES. CORP. 7216 Circle Ave., Forest Park, Ill.	10	1-12-17-26		•	national
PITMAN, E. Norumbega, Camden, Maine	•	6-29			national
POINT CONSULTING CO. Pittsburgh 17, Pa.		1-17			
POLLACK, DALE 352 Pequot Ave., New London, Conn.	10-11-12-25-26			•	national
POLYTECHNIC RESEARCH & DEVELOPMENT CO. 66 Court St., Brooklyn, N. Y.	•	5-8-26		•	national
POMPILTO, M.* Box 172, Livermore, Calif.	12	12	•		100 miles
PRATT, WILLIARD D.* 671 Grant St., Denver, Colo.	5	5		•	national
PRECISION ELECTRONICS, INC.* 5717 Melrose Ave., Chicago, Ill.	5-12-20-25-30			•	national
PREISMAN & BISER 3308 14th St., N. W., Washington, D. C.	4	•	•		500 miles
PRESTON ELECTRONIC LABS., INC. 58 Summer St., Malden, Mass.	•	12		•	500 miles
PRESTON LABS. Box 847, Butler, Pa.		5-17		•	national
PULLEN, F. L. 248 Westmoreland Dr., Baton Rouge, La.		17-22		•	state
PYLE, GEORGE First National Bank Bldg., Peoria, Ill.	4		•		75 miles
R. M. S. ASSOCIATES, INC. 205 Halstead Ave., Mamaroneck, N. Y.	17	17	•	•	national
RACHINSKY, K. K. 1902 S. Benecia Ave., Los Angeles, Calif.	1-2-10-12-17-30	1-2-10-12-17-30			
RACK, EDGAR C.* 1800 Columbus Ave., Waco, Texas		2	•		state
RADIO COMMUNICATION CO.* 6909 Templeton St., Huntington Park, Calif.	10-17			•	state
RADIO ENGR. CO. 8 State St., New York, N. Y.	12-24-25	5-26	•	•	200 miles
RADIO ENGR. CO. 1355 Market St., San Francisco, Calif.	4-11-12		•	•	national
RADIO INVENTIONS, INC. 155 Perry St., New York, N. Y.	10	•	•	•	national
RAMSEY, H. M. 1428 South Cloverdale, Los Angeles, Calif.	10		•		100 miles
RASH, W. Rose Hill, New Castle, Del.	30		•		state
RAY, GARO W. 991 Broad St., Bridgeport, Conn.	4-5-10-11-25-30	1-29	•	•	national
RAYMOND, H. H. Smith St., Middletown, Conn.		21	•	•	national
RAYMOND ENG. LAB., INC. Smith St., Middletown, Conn.	15	15		•	national
RAYTHEON MFG. CO. Waltham, Mass.	•	1	•		100 miles
RAZEK, JOS. 202 Darby Rd., Llanerch, Havertown, Pa.		8		•	national
REED RESEARCH* 1048 Potomac St., N. W., Washington, D. C.	•	1-2-3-5-6-15-17-24	•	•	national
RIEBER, FRANK 127 E. 73rd St., New York, N. Y.	5	9	•	•	national
RING & CO., A. D. Munsey Bldg., Washington, D C.	4		•		national
ROBINETTE CO., W. C.* 802 Fair Oaks Ave., South Pasadena, Calif.		1-2-17	•	•	national
ROBINSON, ODES E. Box 451, Charlestown, W. Va.	4				250 miles
ROGERS ENGR. CO. 546 Grand Ave., Oakland, Calif.		1-2-12-17	•		state
ROHNER, GERRIT, J. Sampson College, Sampson, N. Y.	•	17	•		New England
ROLAB PHOTO SCIENCE LABS.* Sandy Hook, Conn.		15	•	•	national

Name	Communications	Industrial	Design	Models	Area
ROSENBERG ASSOCIATES, PAUL Woolworth Bldg., New York, N. Y.	•	8	•		national
ROTHROCK, HAROLD B. 1901 Eye St., N. W., Washington, D. C.	4		•		national
ROWE ENGINEERING CORP. 2422 Pulaski Rd., Chicago, Ill.	10-25	1-2-5-15	•	•	national
RUBIN, H. B.* 1 Flint St., Poquonock Bridge, Conn.	1-5-12-26			•	1500 miles
RUGBY CONSULTING LABS.* 511 E. 48th St., Brooklyn, N. Y.	8		•	•	100 miles
RUTEMILLER, OREN G. Citizens Bank Bldg., 4812 Vine St., Cincinnati, Ohio		1-2-12-17	•	•	300 miles
SANBORN, PAUL 2602 Riverview Dr., Parkersburg, W. Va.		28			national
SANIAL, ARTHUR J. 168-14 32nd Ave., Flushing, N. Y.	30		•		50 miles
SAVADELIS, I. C. 65 W. Putnam Ave., Greenwich, Conn.	•	1-5-17		•	300 miles
SCHMIDT, W.* 2440 Lake View Ave., Chicago, Ill.		20	•		national
SCHMITT, F. 193-10 99th Ave., Hollis, N. Y.		1-2-17-20	•	•	1000 miles
SCHOTTLAND, FREDERIC D. 104-18 Metropolitan Ave., Forest Hills, N. Y.	4	5		•	national
SCHUTTIG & CO. 9th & Kearney Sts., N. E., Washington, D. C.	20			•	national
SCIENTIFIC RES., INC.* 141 E. Glenside Ave., Glenside, Pa.	5-12	1-2-3-17-22	•	•	state
SCOTT INSTRUMENT LABORATORY 4859 68th St., San Diego, Calif.		5	•	•	100 miles
SCOTT, R. C.* 340 Common St., Belmont, Mass.		1-2-5-8-12-17	•	•	national
SEAVER, F. HARMON 212 S. 4th St., Delevan, Wisc.	10	17		•	national
SEMPLE, PARLAN 328 Passaic Ave., W. Caldwell, N. J.		20	•	•	100 miles
SENSITROL, INC.* 4128 Wilshire Blvd., Los Angeles, Calif.		1-2-3-6-17		•	state
SENTINEL LABORATORIES 1019 Appletree St., Philadelphia, Pa.	5	8-17-27		•	national
SERDEX, INC.* 91 Cambridge St., Boston, Mass.	10	5-11			national
SHAW, GEORGE S. Box 1033, St. Cloud, Fla.	10			•	national
SHAW, S. J. Empire Bldg., Pittsburgh, Pa.	10	•	•		300 miles
SHERMAN INDUS., ELECTRON. CO., INC. 503 Washington Ave., Belleville, N. J.		2-20		•	100 miles
SHEPARD, JR., F. H. 31 Union Place, Summit, N. J.	17	17		•	1000 miles
SHERRON ELECTRONICS CO.* 1201 Flushing Ave., Brooklyn, N. Y.	1-2-4-10-12-17-25-26	1-2-5-11-12-17-29	•	•	600 miles
SICKLES, WALTER E. & ASSOC. 1030 Forbes St., Pittsburgh 19, Pa.	4-25		•		500 miles
SIEVERS, GUS Route 1, Box 182, Mission, Texas	5	5	•		state
SINGLETON & BARNARD 1111 S. W. 5th Ave., Portland, Ore.		20-29	•		national
SMEBY, LYNNE C. 820 13th St., N. W., Washington, D. C.	4				national
SMITH, J. C. 117 E. 24th St., New York, N. Y.		2		•	national
SMUCKLER & CO., A. F. New York 10, N. Y.		15			
SOUTHERN RES. INST.* 917 S. 20th St., Birmingham, Ala.	•	15		•	national
SOWTER, G. A. V. 18, Bushey Way, Beckenham, Kent, Eng.	•	1		•	national
SPAWN, JR., COY U.* 1209 Cleburne, Houston, Texas		5-12-17	•	•	state
SPECTRUM ENGR., INC. 540 North 63rd St., Philadelphia, Pa.	1-17	2-12-17-26-23		•	national
STACEY, DAVID Box 26, Estes Park, Colo.	8	8		•	state
STAND. ELEC. RES. CORP. (X-RAY ELEC. CORP.) 2 East End Ave., New York, N. Y.		5-16-17		•	1000 miles
STAVID ENGR., INC.* 40 Somerset St., Plainfield, N. J.	12	12		•	national
STEEL, LT. COL. W. A.* 4601 Maplewood Ave., Montreal, Canada	4-10		•		national
STEVENS, HERBERT V.* 63 Edser St., Buffalo, N. Y.	15	15	•		500 miles
STEVENS-ARNOLD CO., INC.* 22 Elkins St., S. Boston, Mass.	10-24	17-21-25	•	•	national
STERLING, HOWARD T. 70 Morningside Drive, New York, N. Y.	5	5		•	national
STILES, WALTER J. 75 Federal St., Boston, Mass.	4-10				national
STINER, H. WRAY 701 Investment Bldg., Pittsburgh, Pa.		1-2-17	•		400 miles
STROBO RESEARCH 4351 N. 35th St., Milwaukee, Wisc.		22	•	•	national
SUFFIELD-VOSE 9737 Redfern Ave., Inglewood, Calif.		21-26	•		500 miles
TECHLIT CONSULTANTS, INC. 140 Nassau St., New York, N. Y.		1			500 miles
TECHNITROL ENGR. CO., INC. 3212 Market St., Philadelphia, Pa.		1-2-5-6-17	•	•	Middle Atlantic states
TELEREGISTER LABS. New York, N. Y.		15			
TELEVISION ELECTRONICS CO.* 305 Techwood Drive, N. W., Atlanta, Ga.	10-25-26	17-29	•		300 miles
TELETRONICS LAB. 352 Maple Ave., Westbury, N. Y.	10	1-2-17		•	
TEXAS ELECTRONIC ENTERPRISES Box 1747, Brownsville, Texas	15	15	•	•	international
THERMIONIC ENGR. CORP. Rt. 23, & Blvd., Pompton Plains, N. J.	1-10-17	1-5-7-27-29		•	national
TIFFANY LABORATORIES* Midpines, Calif.	8	8		•	national
TRANS-WORLD ELECTRONICS CORP. 475 5th Ave., New York, N. Y.		1-17-29	•	•	state
TRIPLETT & BARTON, INC. 821 Elwood St., N. Hollywood, Calif.		8-16-17-26		•	state
TURNER, RUFUS P. Rt. 4, New Bedford, Mass.	10	5-17	•	•	national
UEHLING, F.* P. O. Box 716, Passaic, N. J.		1-2-3-5-17	•	•	national
UNIVERSAL ENGINEERING CO. 222 W. Water St., Sandusky, Ohio		1-17-26	•	•	state
UNIVERSAL RESEARCH LAB. 1 Nob Hill Circle, San Francisco, Calif.	4-10-11-25				500 miles

CONSULTING ENGINEERS continued

Name	Communications	Industrial	Design	Models	Area
U. S. RESEARCH & DEVELOP. CORP.* 5151 W. Washington Blvd., Los Angeles, Calif.		29		•	state
U. S. TESTING CO. 1415 Park Ave., Hoboken, N. J.		6-16-25-27-28-30			national
V-D INSTRUMENT LABORATORY 425 W. Whitmore St., Willmar, Calif.		5		•	state
VAN WART, ROBERT Kensico Rd., Thornwood, N. Y.		20-27-29			state
VINCENT, ANDREW M. 300 W. High Ter., Rochester, N. Y.	2-10		•	•	50 miles
VOSS ENGINEERING SERVICE 182 E. 19th St., Brooklyn, N. Y.	4-25-30	•	•		50 miles
WALES LABORATORIES* 6 Whippany Rd., Morristown, N. J.		6-9-15-17-21		•	national
WALKUP, J. F. Overland Park, Kansas		12-17	•		national
WALTON, H. T. 113 E. 14th St., Big Spring, Texas	•	•	•	•	state
WALUK, PETER P. Parcel Post Sta., Box 47, Worcester, Mass.	4	•	•		state
WARREN, C. L.* Easy Street, Canaan, Maine	10			•	state
WARRICK, F. 8686 Grandville, Detroit, Mich.		2	•	•	150 miles
WASH. U. RES. FOUNDATION, APP. MATH. DEPT.* 7443 Cromwell Dr., Clayton, Mo.		17		•	national
WEISS, IRVING* 26 Cornelison Ave., Jersey City, N. J.	1-2-4-5	•		•	national
WELDON & CARR 1605 Conn. Ave., Washington, D. C.	4-10	12	•		international
WELLINGTON, H. 2178 N. 57th St., Milwaukee, Wisc.		1	•		state
WELLS, W.* 307 E. 44th St., New York, N. Y.	5-25-26	8-15-27-30	•	•	national
WELTRONIC CO. Detroit, Mich.	•	17		•	state
WESTERN ELECTRIC & BELL TEL. LAB. 47 St. Marks Pl., Brooklyn, N. Y.	•	15	•	•	national
WHEELER LABORATORIES, INC. 259 Northern Blvd., Great Neck, N. Y.	5-10-12-18-19-26	5-10-12-18-19-26	•	•	national
WHIPPLE & CO.* 114 Liberty St., New York, N. Y.	5-12	1-2-3	•	•	national
WIEDEMAN, GUSTAVE* 122 E. 22nd St.,Room 1403, New York, N. Y.		5		•	state
WILKINSON, JOHN K. 3906 1st St., S. E., Washington, D. C.	4			•	state
WILLIAMS, NATHAN 20 Algoma Blvd., Oshkosh, Wisc.	4-10	11	•		national
WILLIAMSON, PAUL* 5201 Danneel St., New Orleans, La.		1-9-26	•		national
WILMOTTE, INC., RAYMOND M.* 236 W. 55th St., New York, N. Y. and Church St., N. W., Washington,D. C.	4-10-11	17	•	•	national
WISE, INC., ROGER M.* 65 Ongley St., Rockville Center, N. Y.	15	15	•	•	international
WRIGHT, R. E. 1623 5th Ave., San Diego, Calif.		17-21-30	•		national
WYSE LABORATORIES* 211 S. Ludlow St., Dayton, Ohio		1-2-5		•	national
YARDENY LAB. CO., INC.* 105 Chambers St., New York, N. Y.		15-17		•	national
ZENIER, HOWARD AND ASSOCIATES 617 Main St., Lewiston, Idaho	•	1		•	500 miles
ZENOR, H. M. Box 7415, Houston, Texas		5-9		•	national
ZOTTU, PAUL D.* 95 Country Club Rd., Newton Center, Mass.		29	•	•	national

This list of consulting engineers is an expansion of the first list published last year, made possible by the cooperation of readers who pointed out several omissions. We believe it to be complete and accurate, considering the complex field it covers. Any omissions or errors should be reported to us, to assist in compiling the list for next year's Buyers Guide.—The Editors.

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electronics

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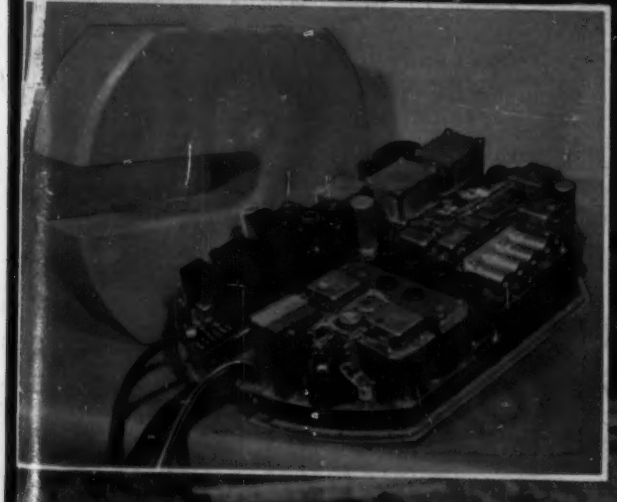

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NEW ANTI-CORONA HIGH VOLTAGE TUBE OPERATES IN OPEN TO 12-MILE ALTITUDES

AMPEREX RESEARCH TACKLED LONG PRESSING PROBLEM AND CAME THROUGH

As jet planes and guided missiles speed through diverse pressure and temperature changes into the thin air twelve miles above sea level, conventional high voltage tube performance drops far below minimum standards and becomes extremely erratic.

The importance of the problem can be seen in the fact that the dielectric strength of air at such altitudes permits standard tube designs to operate at less than *one-fifth* of their ratings.

Two years ago Amperex research teams tackled the problem of designing tubes that would insure sea-level performance, and the associated problem of developing the manufacturing techniques that would put them on a production basis.

The "specs" called for tubes to operate at full rating *in the open* at altitudes up to 60,000 feet where the barometer drops to the troposphere's 2" of mercury and the thermometer sinks to —55°C.

Not only would the tubes have to stand temperatures between the upper air's —55°C. and +250°C. but would have to stand up under a *rate of change* as high as 1°C. per second.

New standards of mechanical ruggedness were called for by hitherto unmet stresses of shock and vibration imposed by the tremendous rates of jet and rocket acceleration. Inevitable moisture and ice formation presented formidable hazards. Cosmic ray showers and other particles were additional challenges.

The first theoretical survey two years ago made it apparent that only a radically different approach could be successful. Amperex is proud to announce that all research and design problems have been surmounted and that the new tube combinations, after prolonged and rigorous testing, are now in production.

HAR-3 is only 4¾" long and 2" in diameter. Of the total tube length approximately 3¼" protrudes above the top plane of the socket. An existing conventional-type tube having approximately the same electrical rating—but at sea level conditions only—is over 8" long and is 2-5/16" in diameter.

"SEALED" CONSTRUCTION SETS NEW STANDARDS FOR ALL EXTREME CONDITION

Problems presented by reliable and e cient operation of high voltage tubes in t open at full rating under extreme con tions of pressure, temperature and str have been solved by a new Amperex dev opment. Tubes incorporating the develo ment are already in production.

Cumbersome containers, pressuriz housings, oil baths and other devices whi added heavily to weight, size, cost and erating complication are now eliminat Tube replacement, often a major operati under old conditions, is now simple a speedy.

Basic to the advance is the concepti of an all-in-one tube and socket combi tion and the use of the combination a single operating unit with the complete clusion of air. This, for the first time practical fashion, eliminates the uncerta ties of air as a dielectric and substitutes advantage of solid dielectrics. The units thus totally independent of outside influen which caused previous open designs to f

After the theoretical solution of the ma problems involved and the making of sco of one-at-a-time prototypes for thoro testing, several novel manufacturing te niques were developed to place the tube units on a production basis to ins extremely reasonable costs and fast delive These shop practices are a natural growth of a quarter century of Ampe experience in electronic tube manufact and the manipulation of materials to cl tolerances.

IMMEDIATE USE SEEN IN INDUSTRIAL FIELDS

Industrial equipment designers and ma facturers are expressing "down-to-earth" terest in the new Amperex applicat developed for use at high altitudes.

Most frequently asked question is: "H about the general run of 'standard' t types? Can they be produced with the vantages of this development?"

The answer is "Yes!"

And it is being done. The developm can be applied to the major number of 340 Amperex tubes now made and c logued. Included are practically all wan industrial types.

Many sea-level conditions such as d moisture, temperature and pressure li full, safe and efficient tube operation. T shorten tube life and increase operat costs. The new Amperex application wh makes the tube unit entirely independ of all significant external atmospheric pressure conditions fills a broad need furnishes the answer to many problems ing designing engineers. Inquiries on sp fic problems are solicited.

AMPEREX RECTIFIER HAR-3 GIVES UNVARYING SEA-LEVEL PERFORMANCE IN OPEN AT ALL PRESSURE, DUST, RADIATION, ICING AND TEMPERATURE EXTREMES TO 60,000 FOOT ALTITUDE

Challenging implications of the new Amperex application to equipment designers and engineers confronted with the necessity for utmost safety and reliability under extreme conditions of pressure, dust, cosmic ray bombardment, icing and temperature are illustrated in the Amperex HAR-3 now in production.

Characteristics apply to operation in the open at any altitude from sea level to 60,000 feet and to any rate of change in altitude.

The tube, a high vacuum, half-wave rectifier rated at 14,000 volts peak inverse, is fully able to handle voltages as high as 35,000 peak.

Average plate current delivery is 125 ma. Tube voltage drop at 100 ma. is 200 volts.

The molybdenum anode, coated with zirconium to provide substantial and continuous *additional* gettering, dissipates an average of 75 watts. The "hard" glass envelope is able to operate continuously at 204°C.

In excess of 2.0 amperes of useful peak emission is supplied by the thoriated tungsten filament when pulsed at 4,000 volts peak. It is rated at 5.0 volts and 10.0 amps.

Dimensions and other information are given under the photograph.

READY FOR YOU:

General technical bulletin on this new Amperex advance, technical rating and data sheets or individually prepared reports on specific industrial sea-level applications.

APPLICATION ENGINEERING DEPARTMENT

AMPEREX ELECTRONIC CORP.
25 WASHINGTON STREET, BROOKLYN 1, N. Y.
In Canada and Newfoundland: Rogers Majestic Limited
11-19 Brentcliffe Road, Leaside, Toronto, Ontario, Canada

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